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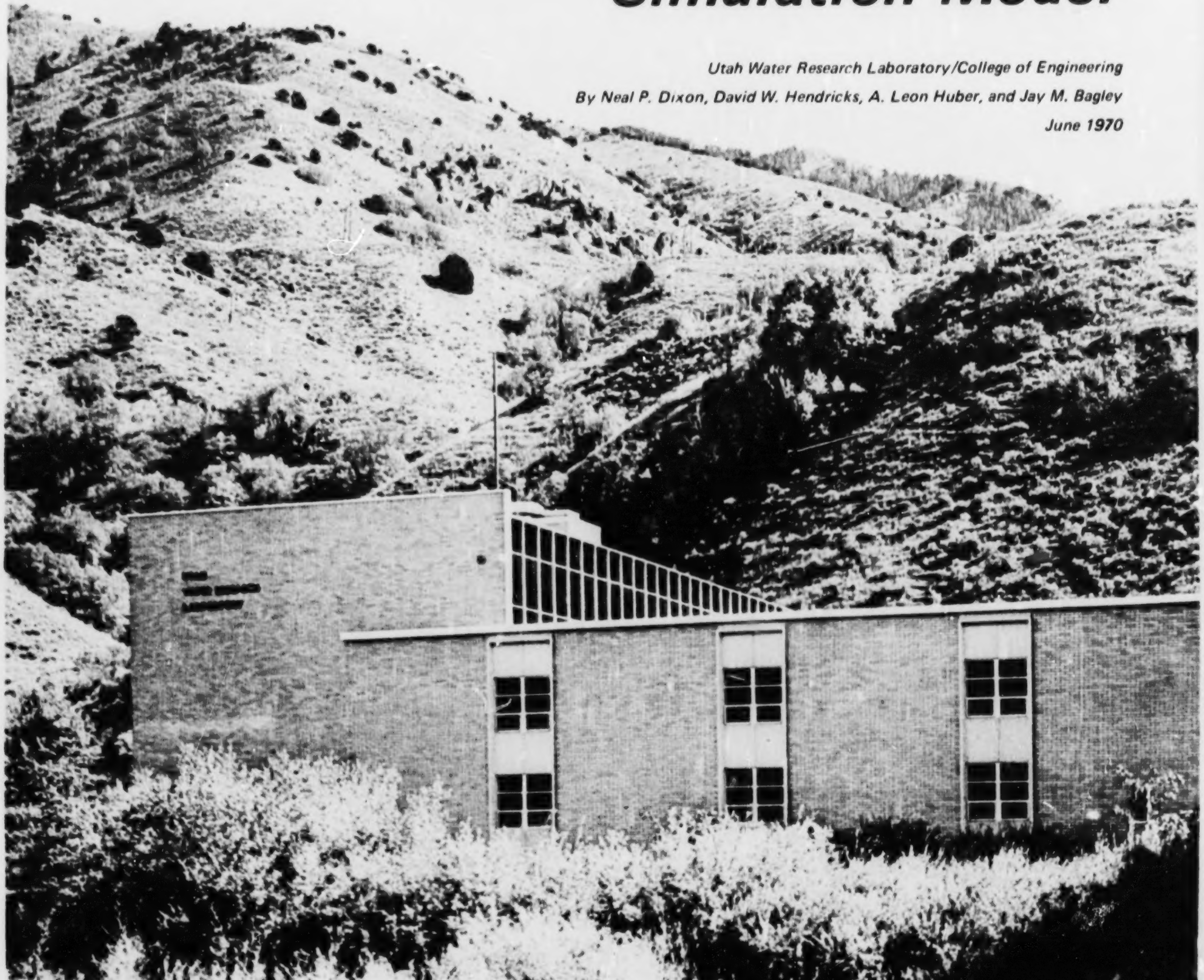
Developing a Hydro-quality Simulation Model

Utah Water Research Laboratory/College of Engineering
By Neal P. Dixon, David W. Hendricks, A. Leon Huber, and Jay M. Bagley

June 1970



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27 Abstract
The development of a river basin simulation model comprising dissolved oxygen, temperature, specific electrical conductance, and basin hydrology submodels is demonstrated. The system model is the device for studying practical questions involving some measure of efficiency - whether this be pollution minimization by treatment and flow regulation, maximizing water use with the quality constraint, maximizing economy efficiency, or in developing more comprehensive water laws. These questions can be ascertained by simulation of altered conditions, sensitivity analysis, or some optimization technique. Although the model in this report was developed for a specific prototype system, the Little Bear River in Utah, the approach, the methods and the conceptual framework can be transferable to other systems. (Woodard-USGS)

Abstractor
T. H. Woodard 14 Sep 70

Institution
U S Geological Survey, Water ResourcesDiv.

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DEVELOPING A HYDRO-QUALITY SIMULATION MODEL

by

Neal P. Dixon
David W. Hendricks
A. Leon Huber
Jay M. Bagley

Utah Water Research Laboratory
College of Engineering
Utah State University
Logan, Utah 84321

June 1970

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PROJECT ORGANIZATION

The project reported herein was begun in February 1966 upon award of a demonstration grant by the Division of Water Supply and Pollution Control, U.S. Public Health Service. Subsequent renewal grants were made by the Federal Water Pollution Control Administration, the third and last being grant number WPD-17-03.

Individuals who have assisted in various phases of the project include:

Mr. Eugene Israelsen—who initiated field studies at the beginning of the project.

Dr. Harvey Millar—who assisted in establishing laboratory chemical analyses procedures and in training the laboratory chemical analyst.

Dr. Frederick Post—who trained laboratory personnel to perform bacteriological analyses, and who initiated the concept of massive data scanning to explore for possible correlations between water quality variables (developed as Appendix H of this report). Dr. Post's motivation was oriented toward explaining bacterial counts in the stream.

Mrs. Ling Chu—who performed most of the chemical and bacteriological analyses on weekly water samples.

Dr. Allen Kartchner—who had the responsibilities of setting up two continuous monitoring field stations and for procuring and analyzing data from same (in collaboration with another project).

Appreciation is expressed to the U.S. Geological Survey, Logan Office, under the supervision of Mr. Wallace Jibson, who under special contract with the project set up four additional gaging stations and made available all current streamflow records in the project area.

Author responsibilities

Jay M. Bagley—conceived the project, initiated the hydrology phases of the study, and was project director at the beginning of the project (until July 1966 when he became Director, Utah Water Research Laboratory).

David W. Hendricks—initiated the water quality phases of the study and was project director, subsequent to Dr. Bagley.

Leon Huber—developed the hydrologic submodel, and was responsible for developing data processing procedures, and for acquisition of hydrologic data.

Neal P. Dixon—developed the water quality submodels, and was responsible for water quality sampling and analyses (Mr. Dixon's doctoral dissertation was based upon his contributions to the project).

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NOTATIONS

Symbol	Definition
A	Fourier series phase angle shift (radians)
a	regression coefficient
A_f	cross-sectional area of flow (sq. ft.)
A_q	antecedent flow index $\left(\sum_{d=1}^{30} \frac{Q_d}{d}\right)$
b	regression exponent
BOD	mean monthly biochemical oxygen demand (mg/l)
$\overline{BOD}$	mean annual biochemical oxygen demand (mg/l)
C	Fourier series coefficient
cf	pressure correction factor for dissolved oxygen saturation concentration
C_s	dissolved oxygen saturation concentration (mg/l)
D	dissolved oxygen deficit (mg/l)
d	number of days counted back from the "k th" day
DDOI	diurnal dissolved oxygen index ($DO_i / \overline{DO}$)
DGW	interflow addition to groundwater during one time increment
DO	dissolved oxygen concentration (mg/l)
$\overline{DO}$	mean daily and mean monthly dissolved oxygen concentration (mg/l)
$\overline{\overline{DO}}$	mean annual dissolved oxygen concentration
DTI	diurnal temperature index ($T_i / \overline{T}$) (mg/l)
E	equilibrium water temperature (°C)
e	naperian log base
EC	electrical conductance within a reach (μ mhos/cm)
ECBR	electrical conductance of branch inflow (μ mhos/cm)
ECEF	electrical conductance of waste discharges (μ mhos/cm)
ECGI	electrical conductance of groundwater inflows (μ mhos/cm)
ECIN	electrical conductance of combined reservoir inflows (μ mhos/cm)
ECIR	electrical conductance of irrigation return flows (μ mhos/cm)
ECS	electrical conductance of diffuse natural surface inflows (μ mhos/cm)
ECST	electrical conductance of water stored in surface reservoirs (μ mhos/cm)
f	constant
f	monthly consumptive use factor
g	regression coefficient
H	mean stream depth (ft.)
Hm	mean stream depth (meters)
h	regression coefficient
i	hour of the day, subscript
j	flow input designation
k	consumptive use coefficient
k_g	interflow groundwater decay constant
k_s	snowmelt constant
k_{sm}	snowmelt constant
K	$K_1 + K_r + K_3$
k_e	heat exchange coefficient (ft./hr.)
K_r	the difference between the actual in-stream deoxygenation rate constant and the laboratory rate constant (base e, day^{-1})
K_1	laboratory deoxygenation rate constant (base e, day^{-1})
k_1	laboratory deoxygenation rate constant (base 10, day^{-1})
K_2	reoxygenation rate constant (base e, day^{-1})

k_2	reoxygenation rate constant (base 10, day^{-1})
K_3	rate constant for BOD removal by sedimentation and/or adsorption (base e, day^{-1})
K_4	rate constant for the anaerobic fermentation of organic benthal deposits (base e, day^{-1})
L_a	ultimate first stage BOD in solution and suspension (mg/l)
L_d	areal BOD of the benthic zone (g/sq. meter)
m	month of the year subscript, beginning with October
N	number of coliform bacteria left in the stream after a given time interval
N_o	maximum coliform density
n	coefficient of nonuniformity or retardation
nc	number of inflow components for a particular reach
O_p	photosynthetically produced oxygen (mg/l)
P	atmospheric pressure (millimeters of mercury)
p	rate of addition of BOD to the stream water from the benthose (mg/l·day)
Pf	photosynthetic oxygen productivity factor (used as a scaling constant)
pv	vapor pressure (millimeters of mercury)
Q	rate of stream flow (cfs)
Q_c	groundwater contribution to flow (cfs)
Q_i	interflow contribution to flow (cfs)
Q_s	surface contribution to flow (cfs)
QBR	tributary branch inflow (cfs)
QD	diversions (cfs)
QEF	municipal-industrial effluent discharges (cfs)
QCI	groundwater inflow (cfs)
QIR	irrigation return flow (cfs)
QS	natural diffuse surface inflow (cfs)
q_j	discharge rate of the "j th" component of flow (cfs)
r	regression coefficient
R^2	coefficient of determination (percent of total variance explained by the model)
R_h	horizontal surface radiation index
R_s	the local radiation index
S	salinity
SM	snowmelt
s	exponent
ΔT	difference between mean monthly and snow threshold temperature
$\overline{T}$	stream temperature (°C)
$\overline{\overline{T}}$	mean daily and mean monthly stream temperature (°C)
T	mean annual stream temperature (°C)
T_a	atmospheric temperature (°F)
T_s	snowmelt threshold temperature
t	time (hours or days)
u	monthly consumptive use of the crop in inches
V	velocity of flow (ft./sec.)
VIN	monthly volume of reservoir inflow (acre-feet)
VOUT	monthly volume of reservoir outflow (acre-feet)
VST	volume of reservoir storage (acre-feet)
w	average surface width for a river reach (ft.)
x	number of days since October first
y	number of coliform bacteria removed during the time of flow below the point of maximum bacterial density
τ_j	temperature of the "j th" component of flow (°C)
τ_j	mean daily and mean monthly temperature of the "j th" component of flow (°C)

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CHAPTER I

INTRODUCTION

Background

River basin planning traditionally has been oriented toward water *quantity* considerations. Planning concepts, however, have evolved gradually in scope and comprehensiveness from the single project level to integrated river basin planning in a systems context (though methods for systems planning have yet to be assimilated formally into planning). Nevertheless, the existing legal structure and institutional framework are designed to support the traditional *quantity* planning procedures.

Comprehensive water *quality* planning developed separately with distinct legislation and administrative entities. Attention to quality began to expand about 1948 with federal legislation. The trend has been given added impetus by state and further federal legislation since that date. A legislative paradox exists, however, in that western water law and traditions of beneficial use are not cognizant of some of the values implicit in recent water quality legislation.

The intensity of river basin development has now increased to such a level that quantity depletion and quality degradation seriously impair both the diversity of uses and the total amount of use. Thus the quality dimension has emerged as one of the paramount factors in water planning, concomitant with the traditional quantity dimension.

Need for modeling

A dichotomy now exists between quantity and quality in legislation, in institutions, in planning concepts and criteria, and in the respective professional disciplines. This dichotomy has been recognized in the Federal Water Quality Act of 1965, which authorizes planning grants to state water planning agencies who incorporate quality considerations in river basin planning. Also, since about 1965, reports in the literature and patterns of professional activities appear increasingly geared to quality-quantity duality. Incorporating the duality concept into practice is difficult, not only because of the traditions in legal and administrative structures, but because it has not been articulated in terms of planning methodology.

Multiple water uses have to be assessed considering quantity-quality requirements and quality degradation for each use, the response of the stream to various quality inputs, and the behavior of the stream in its natural state. This implies the need for a comprehensive river basin model that can simulate the quality-quantity characteristics of the stream and adjacent uses. Such a model of the physical system, while it does not totally satisfy the need for an overall planning approach, does constitute a significant step in that direction. With such a model, planning alternatives can be assessed in terms of desired goals whether this be maximizing water diversions, maintenance of quality, evaluating water quality standards, suggesting alterations in the water rights structure, or examining economic response to imposed alternatives in quality-quantity behavior.

In this report, the development of a water quality-hydrology simulation model is demonstrated, which has at least partial capability for usefulness in the manner described above. The demonstration of methodology of the model development is felt to be more important than the model *per se.*

Objective

The goal in this study was to demonstrate the development of a river basin hydro-quality simulation model, utilizing known principles and knowledge where possible. The model was to simulate the water quality time profile for any given station, or the water quality distance profile along the main channel for a given time. The model should be responsive in time and the one-dimensional space of the stream channel to atmospheric and hydrologic conditions and to time varying waste discharges at various points in the system. Actual field data from a selected prototype river basin system was used to develop and verify the model. The tenor of the study was entirely pragmatic in all respects: the model development dealt with real data and the resulting model was expected to be problem oriented in its potential.

Scope

Although the model is developed for a specific prototype system, the Little Bear River in this case, the approach, the methods, and the conceptual framework can be transferable to other systems, hopefully with less effort than needed for the original study. The model is deterministic in nature. The stochastic nature of some inputs such as atmospheric temperature and basin inflows has not been simulated, though the model could accommodate this feature.

The quality parameters selected for simulation include specific electrical conductivity, dissolved oxygen, and temperature, BOD, and coliform count. Although not a complete definition of water quality, these parameters: (1) are reasonably representative of the range in *types* of water quality parameters, with respect to stream behavior and nature of the parameter; (2) are significant measures of water quality, and (3) could be measured. Item (1) is particularly important because a *pattern* of *modeling* can be established which is reasonably representative of important water quality parameters. The modeling effort for the latter two parameters, BOD and coliform count, was not as exhaustive as for the first three, primarily because of time limitations and the less certain promise of success.

The development of equations for individual water quality parameters is not a primary goal of this study as long as reasonably adequate relationships are available. Therefore, when previously developed equations satisfactorily represented the behavior of a given parameter (as determined by their application to data gathered from the prototype system) they were incorporated into the overall river basin simulation model, as individual parameter submodels. When available relationships did not appear to fit the prototype data, or if no suitable submodel was found, a relationship was developed if this was feasible.

CHAPTER II

PLAN OF OPERATION

Conspectus

Very grossly, the development of the water quality simulation model consisted of defining the following elements:

1. The prototype system. The river basin system was defined with respect to all characteristics that might relate to the quality-quantity response in the main stream. The process included obtaining all relevant hydrologic data, delineating agricultural patterns, and defining waste inputs. In addition, a monitoring program was established to measure surface inflows and outflows, climatological data, and to sample water quality at important spatial node points at regular time intervals.

2. Parameter simulation. For each of the water quality parameters simulated, relationships from the literature were utilized insofar as possible. The first year data from the prototype system were used to determine the most suitable equations and to define coefficients.

3. Hydrology submodel. The system hydrology was developed as a model responsive to inputs of surface inflow and capable of yielding any flow quantities (groundwater or surface) required for simulation of the water quality parameters.

4. Simulation algorithm. Each of the submodels was programmed in Fortran IV for incorporation into an algorithm for simulating the time and space behavior of each parameter. This algorithm comprises the hydroquality simulation model.

The prototype system

The Little Bear River basin at the southern extremity of Cache Valley in northern Utah was selected as the prototype from which data were obtained for model development and verification. This basin was chosen because: (1) its size and definition permitted the meeting of data requirements; (2) problems of nominal magnitude exist in the basin, and its cultural characteristics, hydrologic features, and values of concern were of sufficient variety to be of interest without any one dominating the system; (3) it is reasonably close to Logan.

This basin, described in detail in Appendix A, is a typical intermountain valley, encompassing some 245 square miles. The topography ranges from rolling to rugged with elevations from 4500 feet to 9445 (Figure A-1). The portion of the basin referred to herein as the valley floor generally lies below the 5000 ft. contour, with the area above this elevation being designated as the watershed.

The climate of the region is temperate and semi-arid, with well defined seasons. Monthly averages of mean daily temperature range from 21°F in January to 73°F in July at the nearby Logan, USU weather station (Figure A-3). Normal annual precipitation at this station is 16.6 inches per year, occurring primarily as winter snowfall and spring rains (Figure A-4). Figure A-5 shows the orographic influence of the mountains on the areal distribution of precipitation. Normal annual runoff is on the order of 50,000 acre feet per year, with the bulk of the runoff taking place during the spring snow melt period (Figure A-6).

The project area is predominantly agricultural, containing about 13,000 acres that are farmed, of which 8,100 acres are irrigated. Hay, grain, pasture, and corn are the principal crops. Industries include a cheese plant, two meat packing plants, a rendering plant and a commercial fish farm. The streams, reservoirs, and mountain areas of the system sustain considerable recreational activity, consisting of trout fishing in the stream and the two reservoirs, and boating and water skiing at Hyrum Reservoir, Hyrum State Park. The watershed area and flood plain are heavily utilized for domestic livestock grazing. Tables A-1 and A-2 show estimated numbers and time distribution of grazing units on these areas.

Factors contributing to the organic, chemical, and thermal degradation of the water quality of this system include natural inputs, livestock grazing, return flows from agricultural irrigation, industry, municipal waste discharges, garbage dumps, and recreation. These inputs are both discrete and diffuse in nature.

The city of Wellsville discharges untreated domestic sewage from about one third of its 1500 population, combined with the liquid waste from the cheese factory located there, in a small stream that is tributary to the Little Bear River just below Wellsville. The discharge from the trout farm is the only other discrete input. The other two basin communities (Hyrum and Paradise) and their rural residents employ septic tanks and leach fields for waste disposal. Each of these towns maintains an open garbage dump on the bluffs along the river.

The data collection network established on or near the Little Bear River system is composed of eight streamflow gaging stations, one reservoir stage observation point, five weather stations, 17 weekly water quality sampling stations and two continuous quality monitoring stations. The stream gaging network was designed to account for all surface flows into and out of the basin, plus changes in the main channel. The water quality monitoring system was set up to account for all discrete inputs in the main channel, and important changes in the channel such as reservoirs. These networks are described in detail in Appendix B. Locations and periods of record are shown in Figures B-1 and B-2 and Tables B-1 through B-4.

Resolution

Resolution has to do with the amount of detail in time or space which the model will provide. This must be consistent with needs and with funds of those applying the model. In this model, two levels of time resolution are used—the month and the hour. This was necessary to adequately describe dissolved oxygen and temperature, since they exhibit diurnal variations whose characteristics changed monthly. For electrical conductivity the month was an adequate time increment.

For the space resolution, the main channel and its immediate large tributaries was focused on with respect to water use. Thus the water quality submodels are oriented about the stream channel. The channel was divided into reaches with node points at the significant changes in the channel. This isolates reservoirs and marks discrete inputs into the main channel.

These resolutions in time and space were consistent with the pragmatic tenor of the study—fine enough to be useful but not so fine as to constitute an unwise expenditure of funds.

Submodels

A submodel is defined here as the set of equations and coordinating statements that simulate the behavior of a particular parameter in time and space. The parameters for which submodels were synthesized in this study are: (1) hydrology, (2) electrical conductivity, (3) temperature, and (4) dissolved oxygen. Attempts to develop BOD and coliform submodels were less successful.

Submodel equations were taken from the literature if they existed and were suitable. Considerations used in determining suitability included: (1) ease, feasibility, and cost of data procurement, (2) reliability in simulations using project data, and (3) mathematical complexity. When mathematical equations for phemonena behavior do not exist, such as in diurnal dissolved oxygen and temperature simulation, they were project-developed using project data. Pragmatism was the underlying philosophy, whether the equations ultimately used were project-developed or extracted from the literature and whether empirical or rational.

Equation coefficients and constants were established by regression analysis of first-year field data or by adjusting coefficients such that submodel output corresponded with field measurements. The latter approach was used almost exclusively in the hydrology submodel verification.

Sophistication in theory is justified herein only as (1) data requirements are realistic and obtainable, and (2) the results are commensurate with pragmatic objectives.

In each submodel, the solution consists of two basic parts: (1) the time variation in the respective quality parameters for the incoming flow components for each reach, and (2) the changes in the quality parameter along the reach. For each parameter, the alternative modeling approaches are reviewed, the modeling assumptions are outlined, the approach selected is justified in terms of field data from the Little Bear River, and the simulation algorithm is summarized. Thus, the phenomenological behavior of each component is described in terms of suitable mathematical descriptions and the logic for utilizing those mathematical descriptions in parameter simulation.

Simulation algorithm

The *system control model* is a set of statements designed to: (1) control the manner of operation of the individual submodels, (2) specify the inputs needed to operate the submodels, and (3) provide the necessary feedback between submodels. The Fortran IV program that accomplishes this is given the name WAQUAL. This program contains each of the five submodels.

The system control model embodies the river basin configuration shown in Figure 1, consisting of the main stem and any number of tributaries. The main stem and tributaries are divided into numbered reaches, ascending numerically in the upstream direction. Reservoirs may be included also.

Inputs to the typical nonreservoir reach, as sketched in Figure 2, are considered to be concentrated at the upstream end of the reach and may consist of any one or more of the following:

Q_{i+1} = stream inflow
QS_i = natural diffuse surface inflow
QGI_i = groundwater inflow
QIR_i = surface irrigation return flow
QBR_i = tributary branch inflow
QEF_i = municipal-industrial effluent discharges
i = reach designation

Outflows are assumed to be located at the downstream end of the reach. These outflows may consist of in-stream outflows (QS_i) or diversions (QD_i). All flows are monthly averages in cubic feet per second. In addition to the flows listed above, evaporation, direct precipitation, and change in storage must be considered in the hydrologic simulation of surface impoundments.

A generalized flow chart for the system control model is shown in Figure 3. The simulation begins at the upstream end of the main stem of the surface water system. Moving downstream, each reach is checked for tributary inflow. If a tributary discharges into this reach, control shifts to the upstream end of that tributary and proceeds with the simulation. As each reach is simulated, hydrologic data, describing all the various components of flow pertinent to that reach, are read into the computer. Next, the desired water quality subprograms are called. Subprograms that generate information required in the evaluation of other parameters are run first.

After all quality parameters are simulated for this reach, control passes to the next reach downstream and the process is repeated. When the last reach on a branch is completed, the main stem reach to which that branch is tributary is considered, with the outflow from the tributary branch becoming an inflow (QBR) to the new reach.

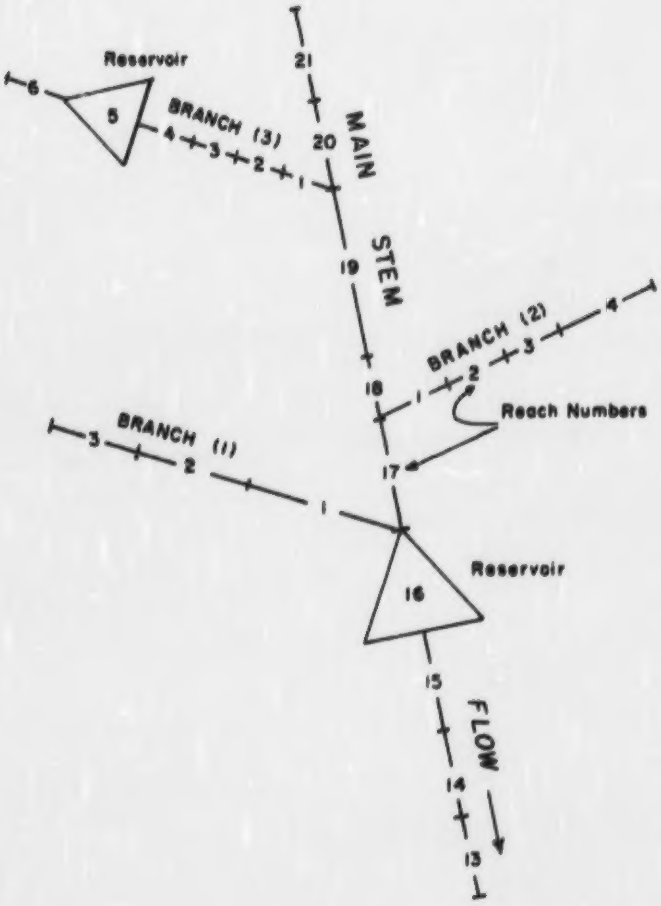
Reservoir
6
5
BRANCH (3)
4
3
2
1
21
20
MAIN
STEM
19
BRANCH (2)
4
3
2
1
18
Reach Numbers
BRANCH (1)
3
2
1
17
Reservoir
16
15
FLOW
14
13

Figure 1. One branch system schematic.

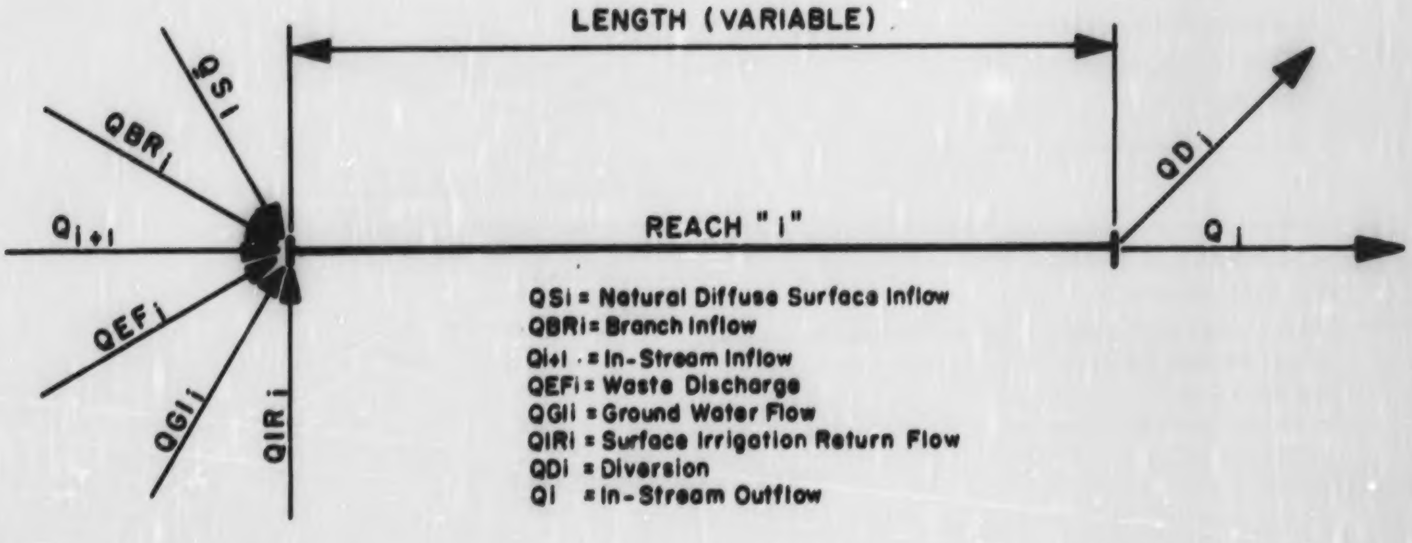
LENGTH (VARIABLE)
QSi
QBRi
Qi+1
QEFi
QGIi
QIRi
REACH "i"
QDi
Qi
QSi = Natural Diffuse Surface Inflow
QBRi = Branch Inflow
Qi+1 = In-Stream Inflow
QEFi = Waste Discharge
QGIi = Ground Water Flow
QIRi = Surface Irrigation Return Flow
QDi = Diversion
Qi = In-Stream Outflow

Figure 2. Typical nonreservoir reach flow components.

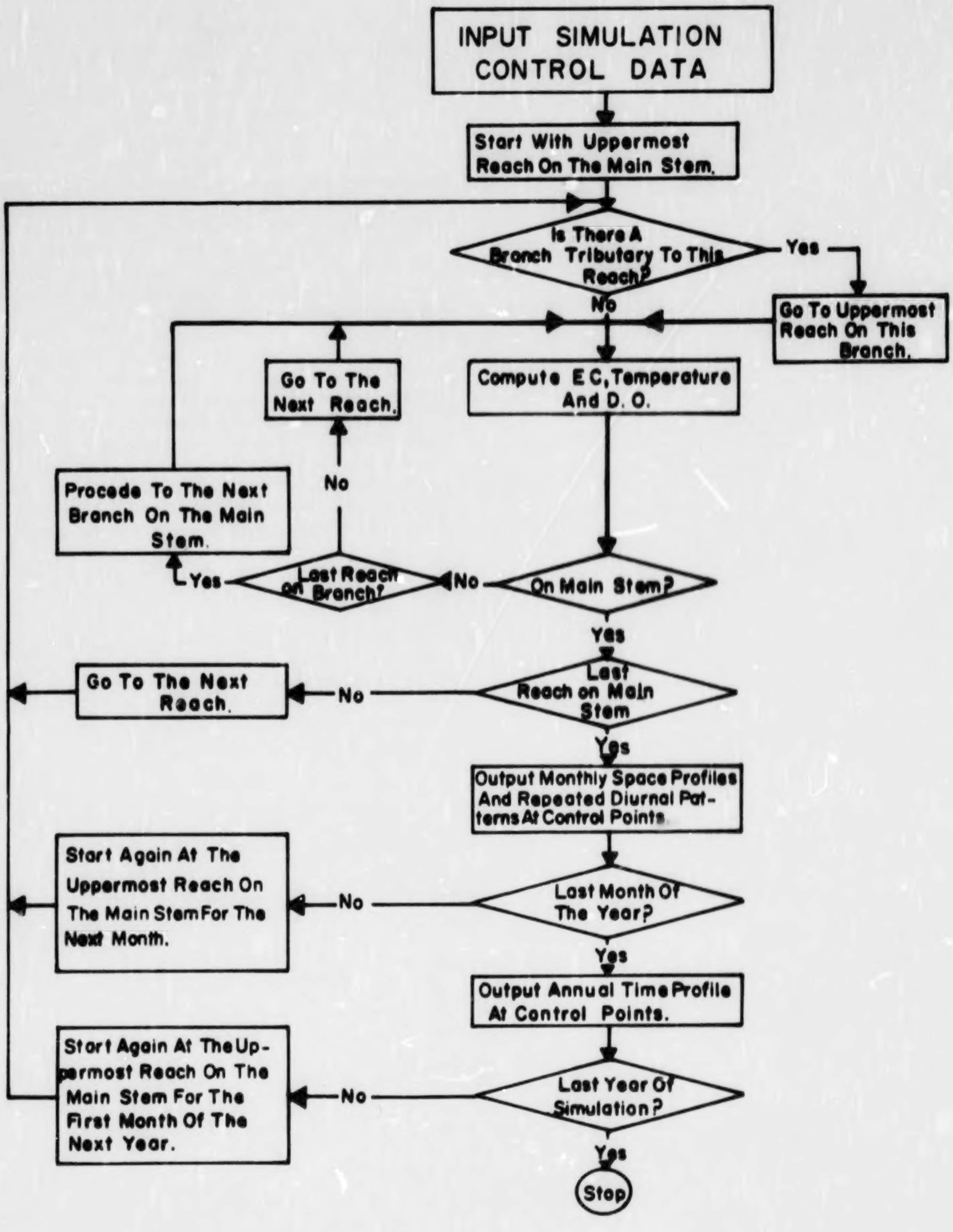
INPUT SIMULATION CONTROL DATA
Start With Uppermost Reach On The Main Stem.
Is There A Branch Tributary To This Reach?
Yes
No
Go To Uppermost Reach On This Branch.
Compute E C, Temperature And D. O.
Go To The Next Reach.
No
Procede To The Next Branch On The Main Stem.
Yes
Last Reach on Branch?
No
On Main Stem?
Yes
Go To The Next Reach.
No
Last Reach on Main Stem
Yes
Output Monthly Space Profiles And Repeated Diurnal Patterns At Control Points.
Start Again At The Uppermost Reach On The Main Stem For The Next Month.
No
Last Month Of The Year?
Yes
Output Annual Time Profile At Control Points.
Start Again At The Uppermost Reach On The Main Stem For The First Month Of The Next Year.
No
Last Year Of Simulation?
Yes
Stop

Figure 3. System control model simulation procedure.

After the last reach on the main stem has been simulated, monthly spatial profiles are printed out in tabular form as shown in Appendix E. These profiles list monthly average values for flow rate, conductivity, temperature, dissolved oxygen, BOD, and percent D.O. saturation at both ends of every reach, as well as the magnitude of these parameters in all hydrologic inputs to the reach. If diurnal representation of stream temperature and/or dissolved oxygen is requested, the predicted diurnal variations in temperature, dissolved oxygen, and percent D.O. saturation are printed out for each predesignated control point.

This procedure is followed until the entire period of simulation has been covered. In addition, annual time profiles of rate of flow, conductivity, temperature, D.O., percent D.O. saturation, and BOD are printed out for predesignated control points at the end of each year of simulation.

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CHAPTER III

THE HYDROLOGY SUBMODEL

The hydrologic mass-balance submodel is a central component of the hydro-quality simulation model developed during the project. The hydrology submodel simulates the area through which the river flows and provides the quality submodels with the flow components that occur as tributary items along the channel. The criteria that had to be satisfied by the submodel were:

1. It had to simulate the hydrologic mass balance of a typical Utah river basin utilizing monthly climatological data, and to yield monthly streamflow data that could be input to the water quality submodels under concurrent development.
2. It had to identify and rapidly evaluate the hydrologic effect of alternative conditions that might or could be imposed upon the study area.

The equation of continuity,

$$\text{Output} = \text{Input} - \text{Changes in Storage} \quad . \; . \; . \quad (1)$$

applied to the mass of water flowing within and through the geographic boundaries of the area provides the conceptual framework for the hydrology submodel. The size of the area to which this submodel may be satisfactorily applied is primarily limited by the degree of spatial resolution required to meet the overall objectives of a particular simulation effort.

For this study, system hydrologic inputs consist of precipitation (PREC), measured stream inflow in the main channel (RIF), measured surface imports (SIMP), and unmeasured surface and subsurface inflow (TIF). The cropland diversions (CD), reservoir storage (RES), municipal and industrial diversions (EMID) net consumptive municipal and industrial use (EMI), pumped water (PW), surface exports (EXPO), and air temperature (TEMP) are other variables supplied as input data to the model.

The system outputs consisted of reservoir evaporation (EVAP), cropland consumptive use (ACU), wetland consumptive use (AWLCU), surface exports (EXPO), municipal and industrial consumptive use (EMI), surface outflow (SOF), and subsurface outflow (GWOF).

The hydrology submodel accounts for monthly changes in: reservoir storage (DRES), cropland soil moisture storage (ASMS), interflow groundwater storage (SGW), wetland soils moisture storage (AWLSM), and groundwater storage (DELGW).

The outflow values are obtained by routing and storing the input quantities through the four principal components of the system which are:

1. Surface water reservoirs
2. Cropland area
3. Interflow routing and groundwater storage
4. Wetland area

A schematic diagram of the hydrology submodel is shown in Figure 4 and a macro flow chart is included as Figure 5. A micro flow chart, computer program notation, data card preparation, user instructions, and problem solutions are given in Appendix G.

Model structure

In any simulation effort, each component of Equation 1 must be carefully selected and evaluated. The various components appearing in Figures 4 and 5 are described in the following paragraphs.

Precipitation

Precipitation is important to the surface reservoir, cropland, and wetland components of the submodel. Its allocation to rain or snow storage is achieved by comparing the mean monthly air temperature with a snow threshold temperature. Any precipitation occurring when the temperature is less than the threshold temperature is accumulated in snow storage and routed through a snowmelt equation of the form

$$SM = k_{sm} S(T_a - T_{sm}) \quad . \; . \; . \; . \quad (2)$$

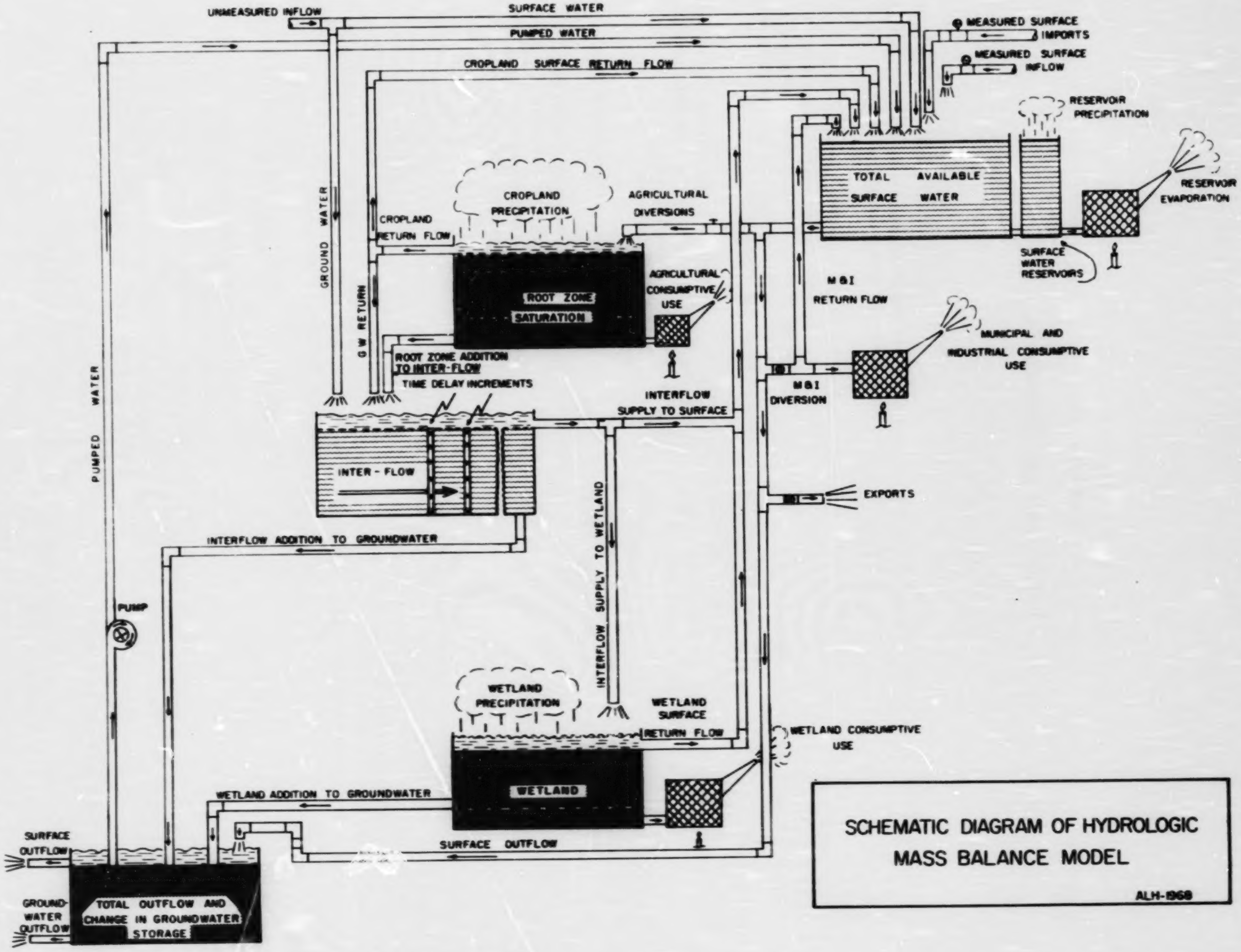

UNMEASURED INFLOW
SURFACE WATER
PUMPED WATER
CROPLAND SURFACE RETURN FLOW
MEASURED SURFACE IMPORTS
MEASURED SURFACE INFLOW
RESERVOIR PRECIPITATION
TOTAL AVAILABLE SURFACE WATER
RESERVOIR EVAPORATION
SURFACE WATER RESERVOIRS
GROUND WATER
CROPLAND PRECIPITATION
AGRICULTURAL DIVERSIONS
CROPLAND RETURN FLOW
G W RETURN
ROOT ZONE SATURATION
AGRICULTURAL CONSUMPTIVE USE
M & I RETURN FLOW
MUNICIPAL AND INDUSTRIAL CONSUMPTIVE USE
ROOT ZONE ADDITION TO INTER-FLOW
TIME DELAY INCREMENTS
INTERFLOW SUPPLY TO SURFACE
M & I DIVERSION
PUMPED WATER
INTER - FLOW
EXPORTS
INTERFLOW ADDITION TO GROUNDWATER
PUMP
INTERFLOW SUPPLY TO WETLAND
WETLAND PRECIPITATION
WETLAND SURFACE RETURN FLOW
WETLAND CONSUMPTIVE USE
WETLAND
WETLAND ADDITION TO GROUNDWATER
SURFACE OUTFLOW
SURFACE OUTFLOW
GROUND-WATER OUTFLOW
TOTAL OUTFLOW AND CHANGE IN GROUNDWATER STORAGE
SCHEMATIC DIAGRAM OF HYDROLOGIC MASS BALANCE MODEL
ALH-1968

Figure 4. Hydrologic model schematic of a water resource system.

in which

SM = snowmelt
k_{sm} = a constant
S = accumulated snow storage through the end of the month
T_a = mean monthly air temperature in degrees F
T_{sm} = snowmelt threshold temperature in degrees F

The rain and snowmelt are then routed through the cropland and wetland components of the system.

Consumptive use

The potential consumptive use by cropland and wetland and the potential evaporation from the reservoirs are obtained by using the method developed by Blaney and Criddle (1950) and modified by the U.S. Soil Conservation Service (1964). The basic Blaney-Criddle equation is:

$$u = kf \quad . \; . \; . \; . \; . \; . \; . \; . \quad (3)$$

in which

u = the monthly consumptive use of the crop in inches
k = an empirically determined consumptive use crop coefficient
f = a monthly consumptive use factor defined as the product of the mean monthly air temperature and the monthly proportion of daylight hours of the year (p)

The Soil Conservation Service modification consists of evaluating k as the product of two other coefficients k_t and k_c, where k_t is a climatic coefficient related to the mean monthly air temperature by the equation $k_t = 0.0173\,T_a - 0.314$ and k_c is a coefficient reflecting the growth stage of the crop. Crop growth stage curves have been developed by the Soil Conservation Service (1964) for a variety of crops and phreatophytes.

Upon substituting the equivalent expressions for k and f, Equation 3 becomes:

$$u = k_c p(0.0173\,T_a^{\,2} - 0.314\,T_a) \quad . \quad (4)$$

where all symbols are as defined previously.

The total potential consumptive use by the cropland and that by the wetland are obtained as the sum of the potential consumptive use by all crops and by all phreatophytes, respectively. These amounts are used as depletive factors in the routing and storage phases of the cropland and wetland components of the submodel. Potential water surface evaporation is treated similarly within the reservoir component of the system. The actual consumptive

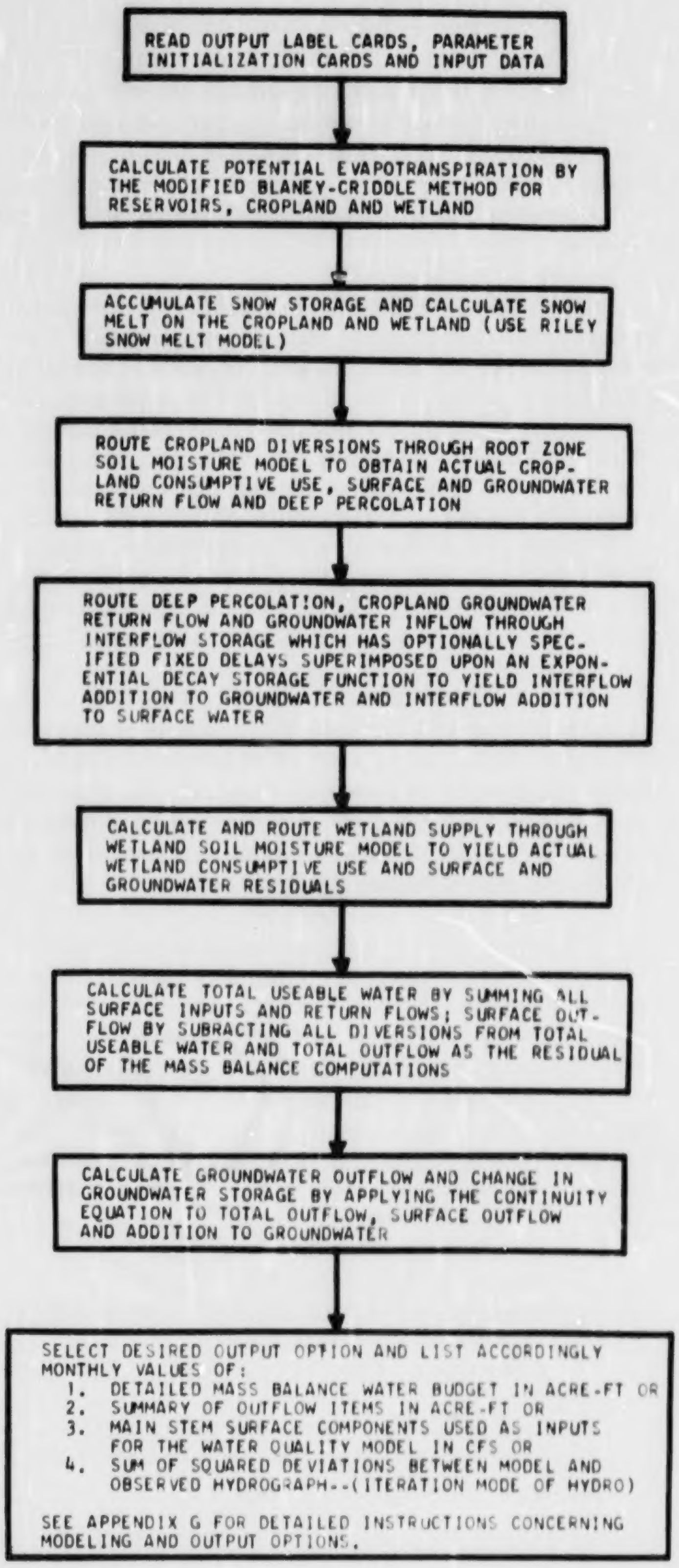

READ OUTPUT LABEL CARDS, PARAMETER INITIALIZATION CARDS AND INPUT DATA
CALCULATE POTENTIAL EVAPOTRANSPIRATION BY THE MODIFIED BLANEY-CRIDDLE METHOD FOR RESERVOIRS, CROPLAND AND WETLAND
ACCUMULATE SNOW STORAGE AND CALCULATE SNOW MELT ON THE CROPLAND AND WETLAND (USE RILEY SNOW MELT MODEL)
ROUTE CROPLAND DIVERSIONS THROUGH ROOT ZONE SOIL MOISTURE MODEL TO OBTAIN ACTUAL CROPLAND CONSUMPTIVE USE, SURFACE AND GROUNDWATER RETURN FLOW AND DEEP PERCOLATION
ROUTE DEEP PERCOLATION, CROPLAND GROUNDWATER RETURN FLOW AND GROUNDWATER INFLOW THROUGH INTERFLOW STORAGE WHICH HAS OPTIONALLY SPECIFIED FIXED DELAYS SUPERIMPOSED UPON AN EXPONENTIAL DECAY STORAGE FUNCTION TO YIELD INTERFLOW ADDITION TO GROUNDWATER AND INTERFLOW ADDITION TO SURFACE WATER
CALCULATE AND ROUTE WETLAND SUPPLY THROUGH WETLAND SOIL MOISTURE MODEL TO YIELD ACTUAL WETLAND CONSUMPTIVE USE AND SURFACE AND GROUNDWATER RESIDUALS
CALCULATE TOTAL USEABLE WATER BY SUMMING ALL SURFACE INPUTS AND RETURN FLOWS; SURFACE OUTFLOW BY SUBRACTING ALL DIVERSIONS FROM TOTAL USEABLE WATER AND TOTAL OUTFLOW AS THE RESIDUAL OF THE MASS BALANCE COMPUTATIONS
CALCULATE GROUNDWATER OUTFLOW AND CHANGE IN GROUNDWATER STORAGE BY APPLYING THE CONTINUITY EQUATION TO TOTAL OUTFLOW, SURFACE OUTFLOW AND ADDITION TO GROUNDWATER
SELECT DESIRED OUTPUT OPTION AND LIST ACCORDINGLY MONTHLY VALUES OF:
1. DETAILED MASS BALANCE WATER BUDGET IN ACRE-FT OR
2. SUMMARY OF OUTFLOW ITEMS IN ACRE-FT OR
3. MAIN STEM SURFACE COMPONENTS USED AS INPUTS FOR THE WATER QUALITY MODEL IN CFS OR
4. SUM OF SQUARED DEVIATIONS BETWEEN MODEL AND OBSERVED HYDROGRAPH--(ITERATION MODE OF HYDRO)
SEE APPENDIX G FOR DETAILED INSTRUCTIONS CONCERNING MODELING AND OUTPUT OPTIONS.

Figure 5. Flow chart for hydro model.

use values may be less than the potential values if not enough water is routed into the soil moisture storage elements of the cropland and the wetland to satisfy the potential requirements. Any surplus water is used to fill the soil moisture storage to its capacity, after which the remaining surplus from the cropland component is routed through the interflow storage component of the model, and any surplus from the wetland soil moisture element is transferred to groundwater storage.

Interflow

Interflow groundwater storage includes water that is in transition between the surface and the groundwater basin and vice versa. The interflow component of the model causes a time delay and smoothing of the groundwater components of unmeasured inflow and cropland return flow and any surplus water or deep percolation from the cropland soil moisture storage. Two types of time delays are incorporated in the interflow equation. The first is a fixed time that is specified in monthly increments as a submodel parameter option. All water entering the interflow storage is held there until the specified time has elapsed unless the storage is at capacity, in which case the surplus is immediately routed to the surface supply. All water that has been in interflow storage for a time equal to or longer than the fixed delay is transferred to groundwater storage through the decay equation:

$$DGW_i = k_g \, [\bar{S}_{gw}] \quad . \; . \; . \; . \; . \quad (5)$$

in which:

DGW_i = interflow addition to groundwater during time increment i

k_g = interflow groundwater decay constant

$\bar{S}_{gw}$ = average amount of water that has been in interflow storage for a time equal to or greater than the fixed delay. This quantity is equal to one half of the sum of the quantity in storage at the beginning of the time increment and the storage at the end of the time increment or

$$\bar{S}_{gw} = 1/2 \; [TRI_i + (TRI_i + SGW_i - DGW_i)] \quad . \quad (6)$$

in which

TRI_i = water in interflow storage longer than the fixed delay at the beginning of the time increment i

SGW_i = water in interflow storage for a time equal to the fixed delay at the beginning of the time increment i

Upon substituting (6) for $\bar{S}_{gw}$ in Equation 5 and solving for DGW Equation 5 becomes:

$$DGW_i = \frac{k_g}{2 + k_g} \; (2 \; TRI_i + SGW_i) \quad . \quad (7)$$

The values of the various quantities transferred from interflow storage must always be positive and a provision is available to transfer a minimum amount to groundwater storage during each time increment if the interflow storage meeting the time qualifications is large enough to satisfy it.

Groundwater. The groundwater basin is not modeled explicitly, but all items that go into or come from groundwater storage are accounted for, and the change in groundwater storage is identified. The groundwater outflow is usually treated as a submodel parameter and determined by iteratively operating the submodel until reasonable changes in groundwater storage are obtained. The submodel allows an estimate to be made of the proportion of the total annual residual that is groundwater outflow. If this option is used, the estimated annual groundwater outflow is proportionally distributed through the months of the year relative to the monthly groundwater additions.

M & I. Municipal and industrial flows were not simulated by a deterministic equation because of the great diversity of M & I users, each of which would require a separate equation. The hydrology submodel requires that the M & I diversions and net depletive use be entered as input data. The actual depletive or evapotranspirative use must be determined independently.

Other elements. The remaining elements of the submodel consist of measured or estimated values for the river surface inflow (RIF), the surface imports (SIMP), the surface exports (EXPO), the pumped water (PW), the gaged outflow (GFLO), the cropland or agricultural diversion (CD), and the unmeasured inflow (TIF). The values needed for the quality submodels are obtained by converting the required elements of the hydrology submodel from acre-feet per month to cubic feet per second. When W_i is the conversion coefficient for month i:

Surface channel inflow (QI_i) = $W_i \; RIF_i$

Unmeasured surface inflow (QS_i) = $W_i \; STIF_i$

Groundwater to surface (QGI_i) = $W_i \; (SINT_i + WLSFC_i)$

Total diversions (QD_i) = $W_i \; (CD_i + EXPO_i + EMID_i)$

Cropland return flow (QIR_i) = $W_i \; SRTF_i$

M & I effluent or return flow (QEF_i) = $W_i \; EMIR_i$

Surface outflow (QO_i) = $W_i \; SOF_i$

These values are computed and obtained as optional output from the hydrologic submodel whenever specified.

Submodel parameters. Although each component and element of input data may, under specific circumstances, be treated as a submodel parameter, the parameters ordinarily consist of coefficients of routing functions, threshold values for selective routing, storage capacities and boundary conditions of the various submodel components. These parameters are explained in detail in the user instructions contained in Appendix G.

Stochastic aspects

The stochastic aspect of the hydrology submodel can be achieved by inputing historical data for a long period of years and then calculating the mean and standard deviation of every element in the resulting mass budgets. The entire output resulting from the historical data input is available for either calculating higher order moments to more fully characterize the distribution or ranking the data to obtain the empirical probability distributions.

The above method for obtaining stochastic information was selected because of major limitations in the other two methods that were considered. The first alternative method (inputing data, all having the same probability level of occurrence that had been derived from probability analyses) was rejected because of no satisfactory method for handling the interactions between the probability distributions of the various input elements such as precipitation, temperature, and streamflow.

The second alternative method evaluated used random process generating techniques to supply the input data to the model. This method was rejected because when these techniques were applied to Utah streams, they failed to synthesize realistic sequences of extreme events. Since these are the critical values about which information is needed, the validity of the method was questionable. A study which supports this conclusion is reported by Jeppson and Clyde (1969). Mandelbrot and Wallis (1968) have observed the same limitation and are working on techniques that may eventually improve the situation.

Two versions of the hydrology submodel were programmed (Appendix G). The same input data are used by both computer programs supplied in the same format. The first program (HYDRO) provides only one year of simulation but has the capability of iterating along many of the model parameters, which is helpful during the validation process. The other program (BUDGET) does not have the iteration capability but allows simulation of up to 30 years and provides a mean mass balance budget and standard deviation budget.

Hydrology modeling of the study area

The study area was divided into two subareas for hydrologic modeling purposes: one, called the Paradise subarea, ran from and including Porcupine Reservoir to the Paradise stream gage (10-1060) that is maintained by the U.S. Geological Survey; and the second, ran from the Paradise gage to the Wellsville stream gage (10-1076), and is called the Wellsville subarea (Figure 6). These two subareas were selected because they both had gaged or observed streamflow data available for validating the submodel and because they were both close to the lower limit of resolution of the hydrology submodel and the available hydrologic data.

Hydrologic data collection and compilation

The input data necessary to operate the hydrologic submodel consists of streamflow, diversions, temperature and precipitation, soil water holding capacity, reservoir storage, well and spring flow, and land use data. Sources for these data included the U.S. Geological Survey, U.S. Weather Bureau, Utah State Engineer, U.S. Bureau of Reclamation, and the U.S. Soil Conservation Service.

Surface flow

Streamflow gages maintained by the U.S. Geological Survey provided input data for both subareas. For the Paradise subarea these were the gage above Porcupine Reservoir (10-1049) and the gage on the South Fork below Davenport Creek (10-1047). Gaging station 10-1060 provided input data for the Wellsville subarea as well as providing outflow values for validating the Paradise submodel. USGS gaging station 10-1076 provided the outflow data for validating the Wellsville submodel.

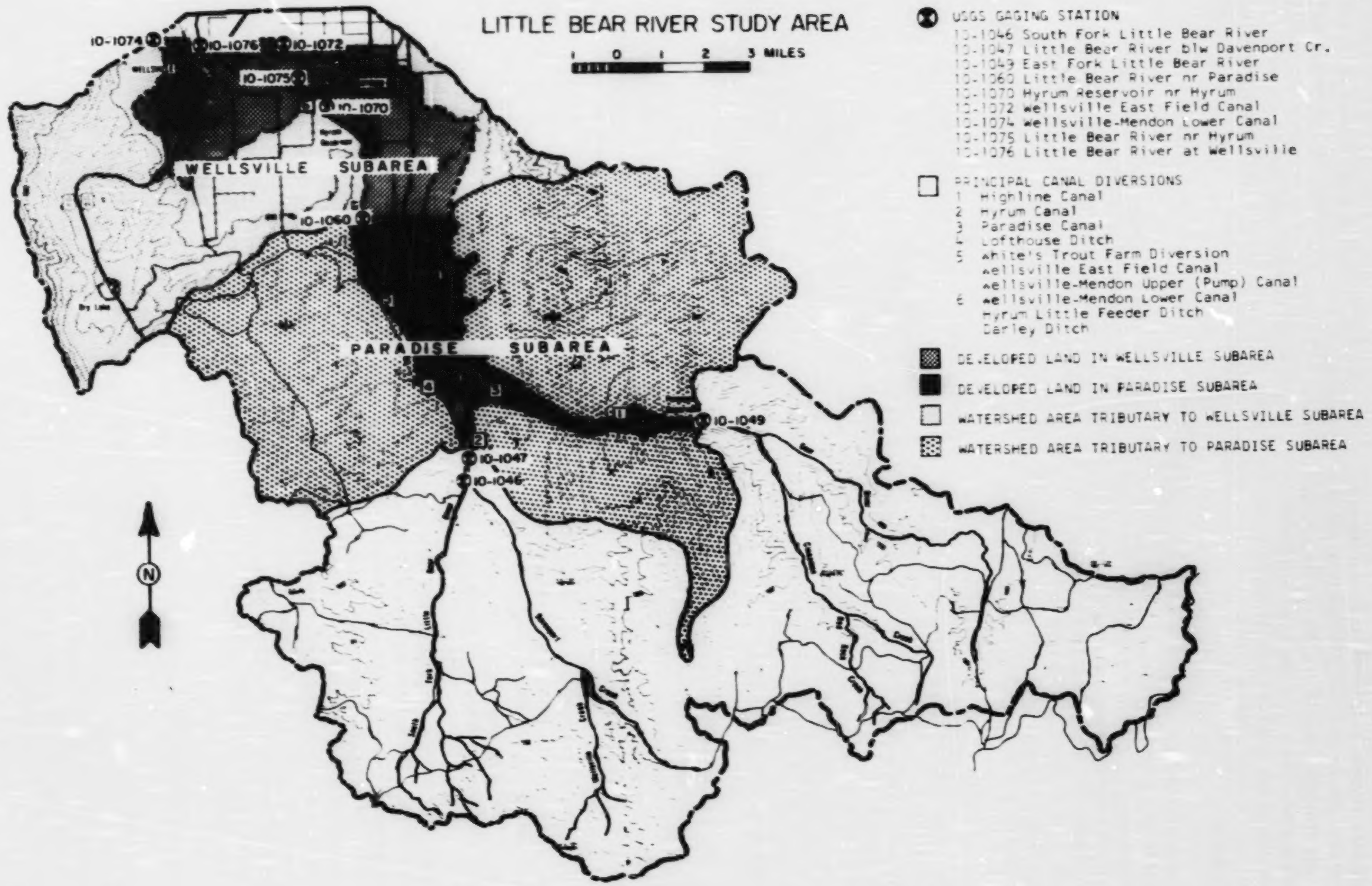
The Paradise subarea had one surface water export, the Hyrum Canal, carrying water to the Wellsville subarea. Flow data for the Hyrum Canal were obtained from the Little Bear River Water Commissioner's Annual Reports to the Utah State Engineer. Surface diversions to the cropland area were also obtained from the Little Bear River Water Commissioner's Annual Reports to the Utah State Engineer, as were the surface water storage data for Porcupine and Hyrum Reservoirs. The Wellsville subarea had two surface exports, the Wellsville East Field Canal near Hyrum and the Wellsville Mendon lower canal at Wellsville. Data for these were obtained from the USGS gages 10-1072 and 10-1074 respectively.

Precipitation

Precipitation data used for the hydrologic submodel were obtained from records of the U.S. Weather Bureau gage located at Utah State University. The isohyetal map of Utah prepared by the U.S. Weather Bureau and published in the "Hydrologic Atlas of Utah" (Jeppson et al., 1968) showed that the Logan USU gage would adequately represent the precipitation on the study area.

Temperature

The temperature values used in the consumptive use component of the hydrologic submodel were obtained from the records of the U.S. Weather Bureau station (Logan USU) that is located at Utah State University.



LITTLE BEAR RIVER STUDY AREA
1 0 1 2 3 MILES
10-1074
10-1076
10-1072
10-1075
10-1070
WELLSVILLE SUBAREA
10-1060
PARADISE SUBAREA
10-1049
10-1047
10-1046
N
USGS GAGING STATION
10-1046 South Fork Little Bear River
10-1047 Little Bear River blw Davenport Cr.
10-1049 East Fork Little Bear River
10-1060 Little Bear River nr Paradise
10-1070 Hyrum Reservoir nr Hyrum
10-1072 Wellsville East Field Canal
10-1074 Wellsville-Mendon Lower Canal
10-1075 Little Bear River nr Hyrum
10-1076 Little Bear River at Wellsville
PRINCIPAL CANAL DIVERSIONS
1 Highline Canal
2 Hyrum Canal
3 Paradise Canal
4 Lofthouse Ditch
5 White's Trout Farm Diversion
Wellsville East Field Canal
Wellsville-Mendon Upper (Pump) Canal
6 Wellsville-Mendon Lower Canal
Hyrum Little Feeder Ditch
Darley Ditch
DEVELOPED LAND IN WELLSVILLE SUBAREA
DEVELOPED LAND IN PARADISE SUBAREA
WATERSHED AREA TRIBUTARY TO WELLSVILLE SUBAREA
WATERSHED AREA TRIBUTARY TO PARADISE SUBAREA

Figure 6. Two hydrologic subareas.

These data were used because a comparison of the mean monthly maximum and minimum temperatures at Logan USU and at the E. K. Israelsen farm near Paradise (Figure 7) indicated that the USU data were sufficiently representative of the model area to be used without adjustment.

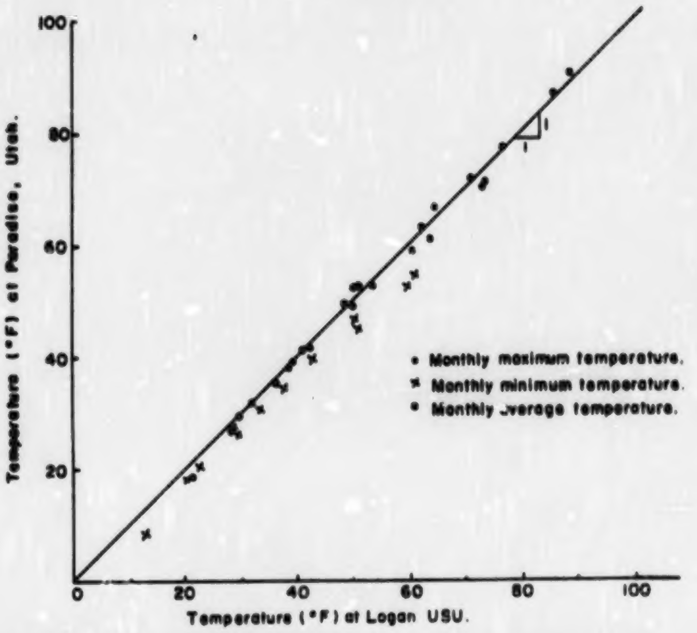


Figure 7. Temperature comparisons—Utah State University Climatological Station and E. K. Israelsen Farm in Hyrum.

Land use

There are eight crop categories; data for determining acreages were obtained from the report "Water Related Land Use in the Bear River Drainage Area" by Haws (1969). Data on the five classes of phreatophyte uses in the wetlands and the surface water evaporating from the two reservoirs (Table 1) were also obtained from Haws (1969).

The growth stage coefficient curves for the crops, phreatophytes and water surface were modifications of those developed by the Soil Conservation Service (1964) for California. The information contained in Technical Publication No. 8 of the Utah State Engineer (1962) was utilized in effecting the modifications. The growth stage coefficient curves developed for use in the submodel are given in Figure 8.

Unmeasured or tributary inflow

The first values used for the unmeasured or tributary inflow were those obtained from the mean annual iso-runoff map in the "Hydrologic Atlas of Utah" (Jeppson et al., 1969). The map shows runoff distributed through the months and proportioned by the year at the same level as the sum of the two virgin gaged inflows to the Paradise subarea. Model validation could not be achieved with these data. The values that were finally used were obtained by treating unmeasured inflow as a model parameter until validation was achieved. The resultant values were then extended to obtain monthly proportionality coefficients for relating unmeasured inflow to measured inflow. The measured inflow to the Paradise subarea was used as the basis for estimating the unmeasured inflow in both subareas because it represented virgin flow conditions.

Municipal and industrial use

Apart from agricultural uses which were explicitly modeled by the cropland component of the submodel, the only significant M & I diversion in the Paradise subarea consisted of a trout farm. Input data for this element of the model were derived from actual measurements of the diversion and return flows where these occurred within the system. The Wellsville subarea had one effluent point (the Wellsville stream) which was also measured and thus provided the input data for the M & I component of that subarea.

Hydrology submodel results

After collecting the records from various sources, the data were prepared for input to the computer. As the validation process proceeded, some of the basic data were found to be in error and thus had to be changed. However, the process by which the errors were discovered aided materially in understanding the systems.

The general procedure followed in validating the hydrology submodel was to first achieve a balance in the annual figures and then work on the monthly distribution. By iteratively operating the submodel, validation was achieved (Figure 7). Figure 9 gives a comparison between the gaged and computed outflow for both subareas for the water years 1967 and 1968. A summary of the flow values generated for the water quality submodels is given in Table 2. A complete listing of the input data, water budgets, consumptive use calculations, and water quality hydrologic data is included in Appendix G.

Hydraulic considerations

In-transit changes in water quality often depend directly upon the mechanics of flow in the stream. The reaeration coefficient of the dissolved oxygen model is dependent upon velocity and depth of flow; the rate of temperature change depends upon, among other things, the surface area of the stream; and time of travel through a reach is determined by the velocity of flow. Because of these dependencies, depth and velocity of flow and surface width must be defined.

Table 1. Water related land use acreage for the Paradise and Wellsville subareas of the Little Bear River basin.[a]

CROPLAND

Crop	Mnemonic	Paradise Acres	Subarea Percent	Wellsville Acres	Subarea Percent
Alfalfa	ALFALF	1094	29.7	2657	28.4
Pasture	PASTRE	692	18.8	1824	19.5
Hay	HAY	169	4.6	215	2.3
Grain	GRAIN	932	25.3	2311	24.7
Corn	CORN	122	3.3	253	2.7
Sugar Beets	BEETS	52	1.4	94	1.0
Truck Crops	TRUCK	85	2.3	150	1.6
Idle Land	UR-IDL	538	14.6	1852	19.8
Cropland Total		3683	100.0	9355	100.0

WETLAND

Phreatophyte	Mnemonic	Paradise Acres	Subarea Percent	Wellsville Acres	Subarea Percent
Very Dense–very high water use	VRDNPH	155	9.1	216	13.5
Dense–high water use	DNSPHY	818	48.1	354	22.1
Medium–water use	MEDPHY	498	29.3	350	21.9
Light–water use	LTPHRY	229	13.5	374	23.4
Very light water use	VLTPHY	0	0.0	306	19.1
Wetland Total		1700	100.0	1600	100.0
Surface Water in Reservoir Storage (WATER) (acres)		193		372	
Total Area in Acres		5576		11,327	

[a] Data obtained from maps and tabulations given in *Water Related Land Use in the Bear River Drainage Area* by Haws (1969).

Figure 8A.

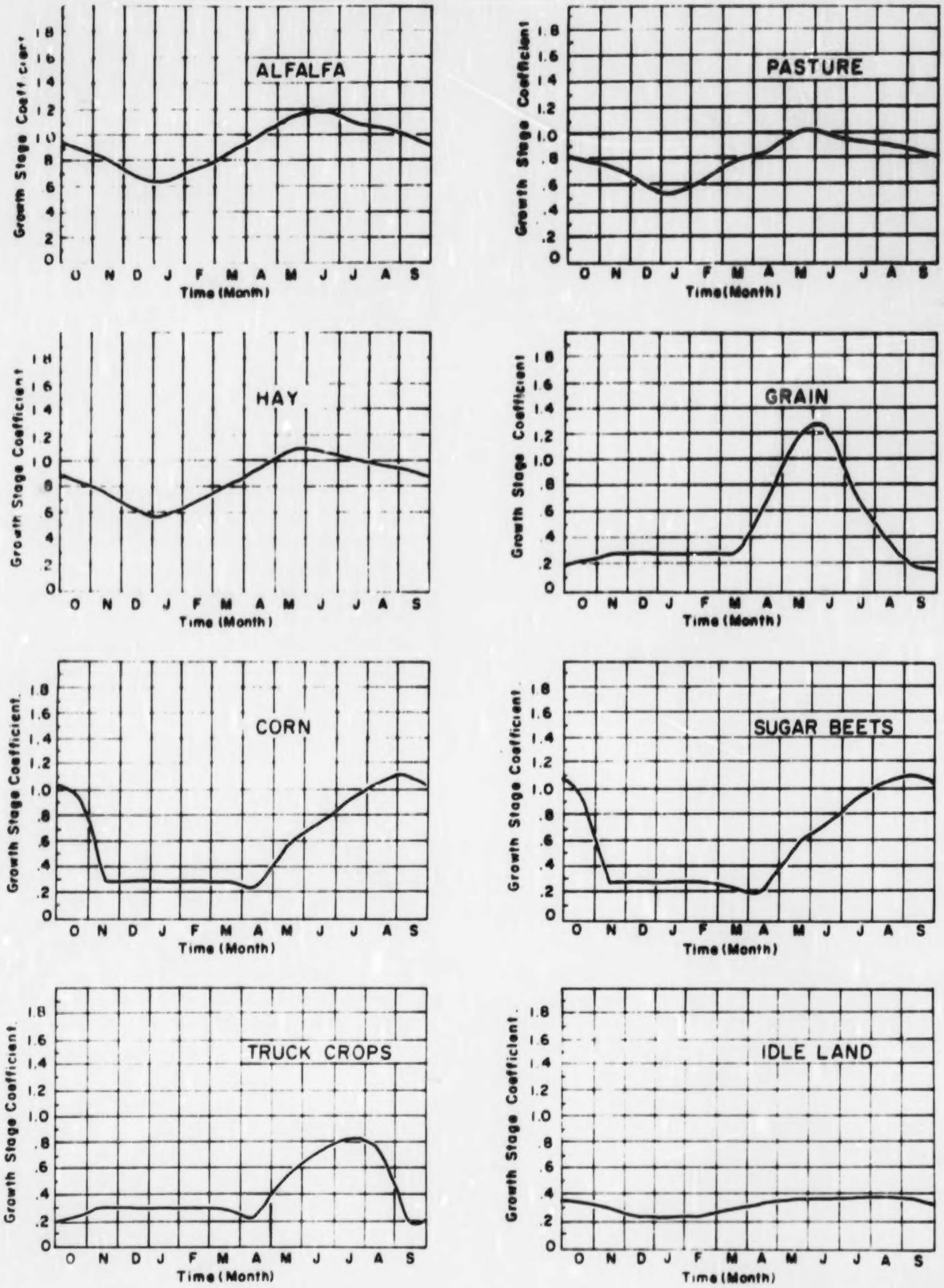


Figure 8. Phreatophyte growth stage coefficient curves.

Figure 8B.

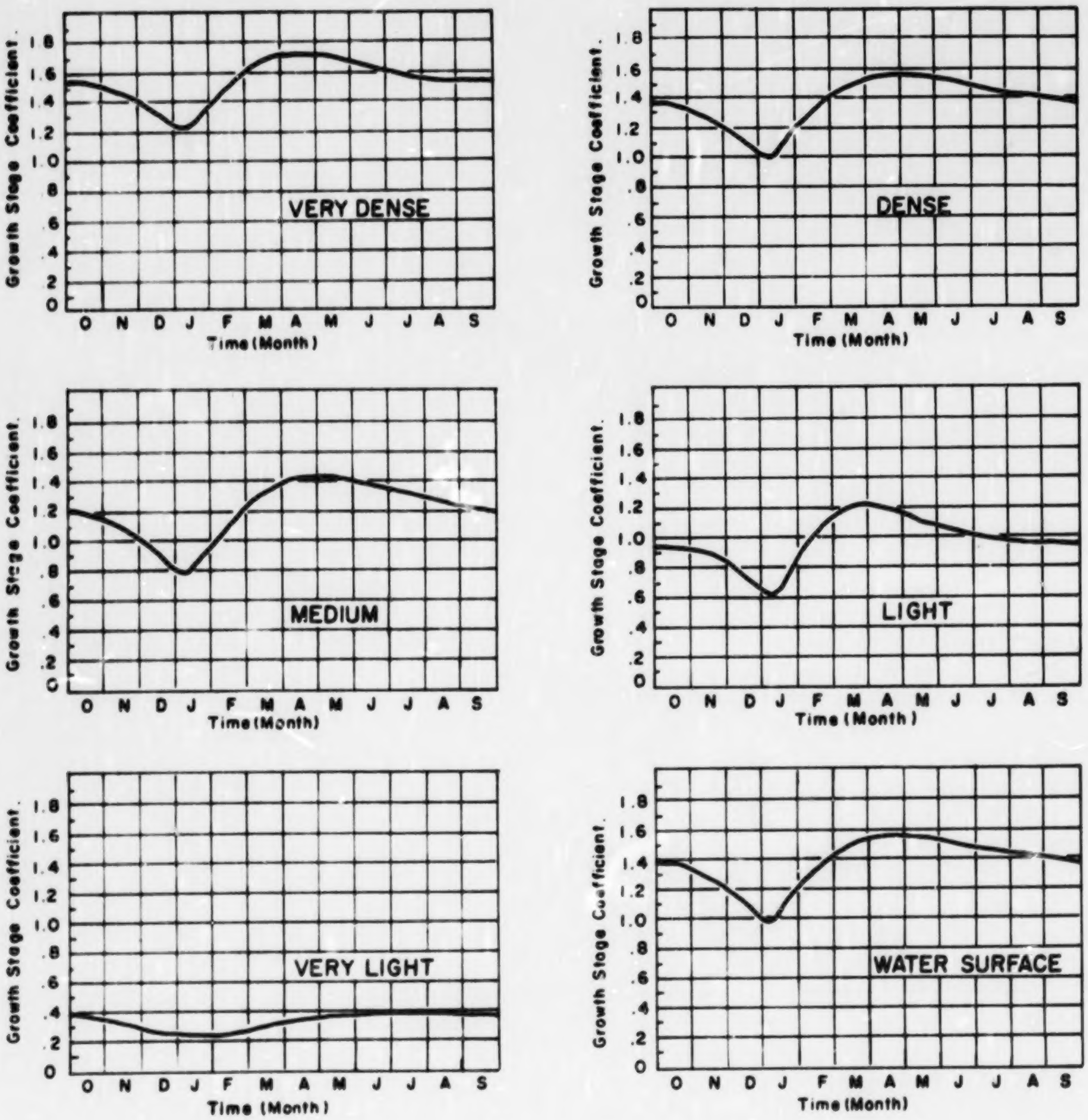


Figure 8. Continued.

Figure 9A.

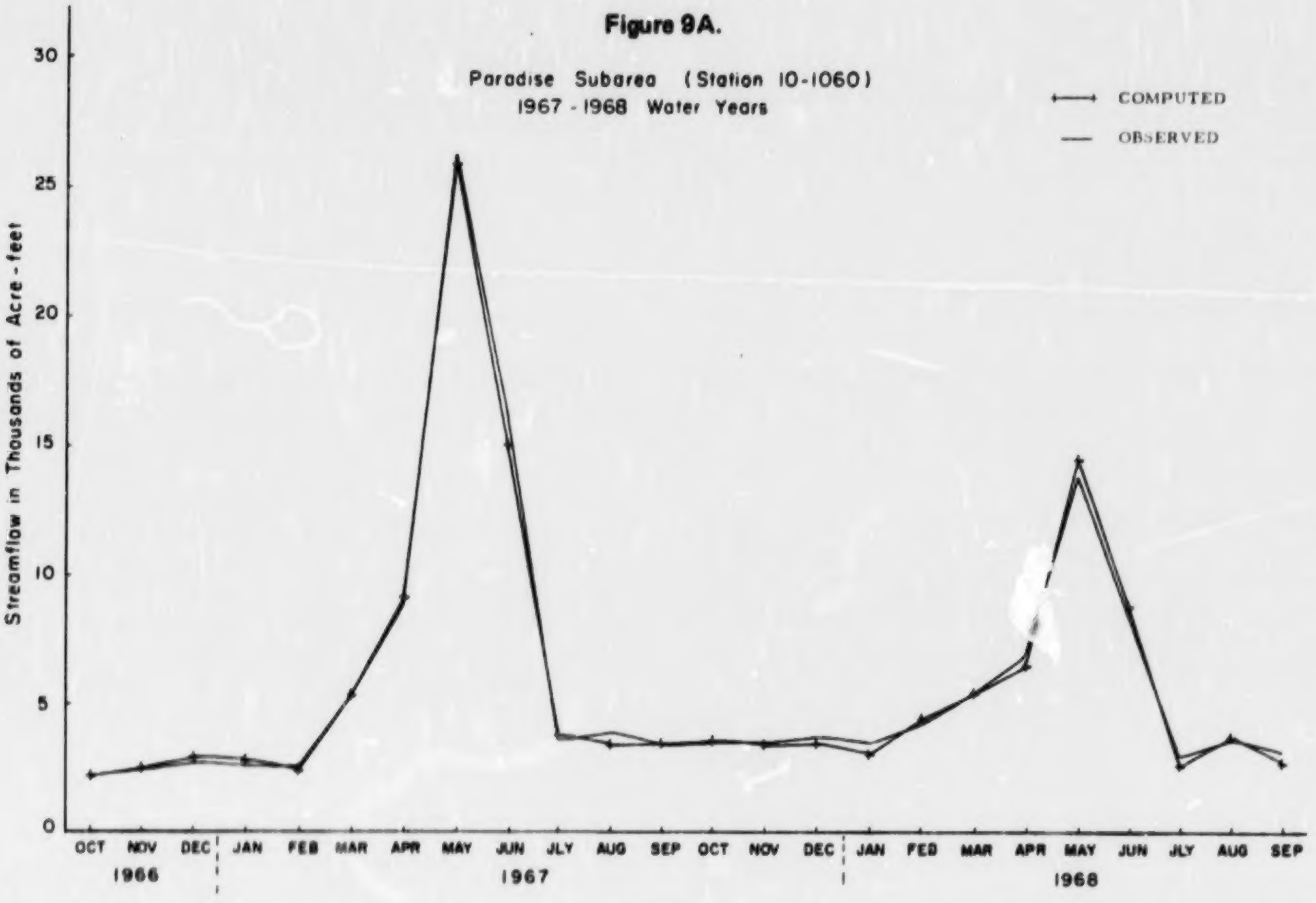


Figure 9B.

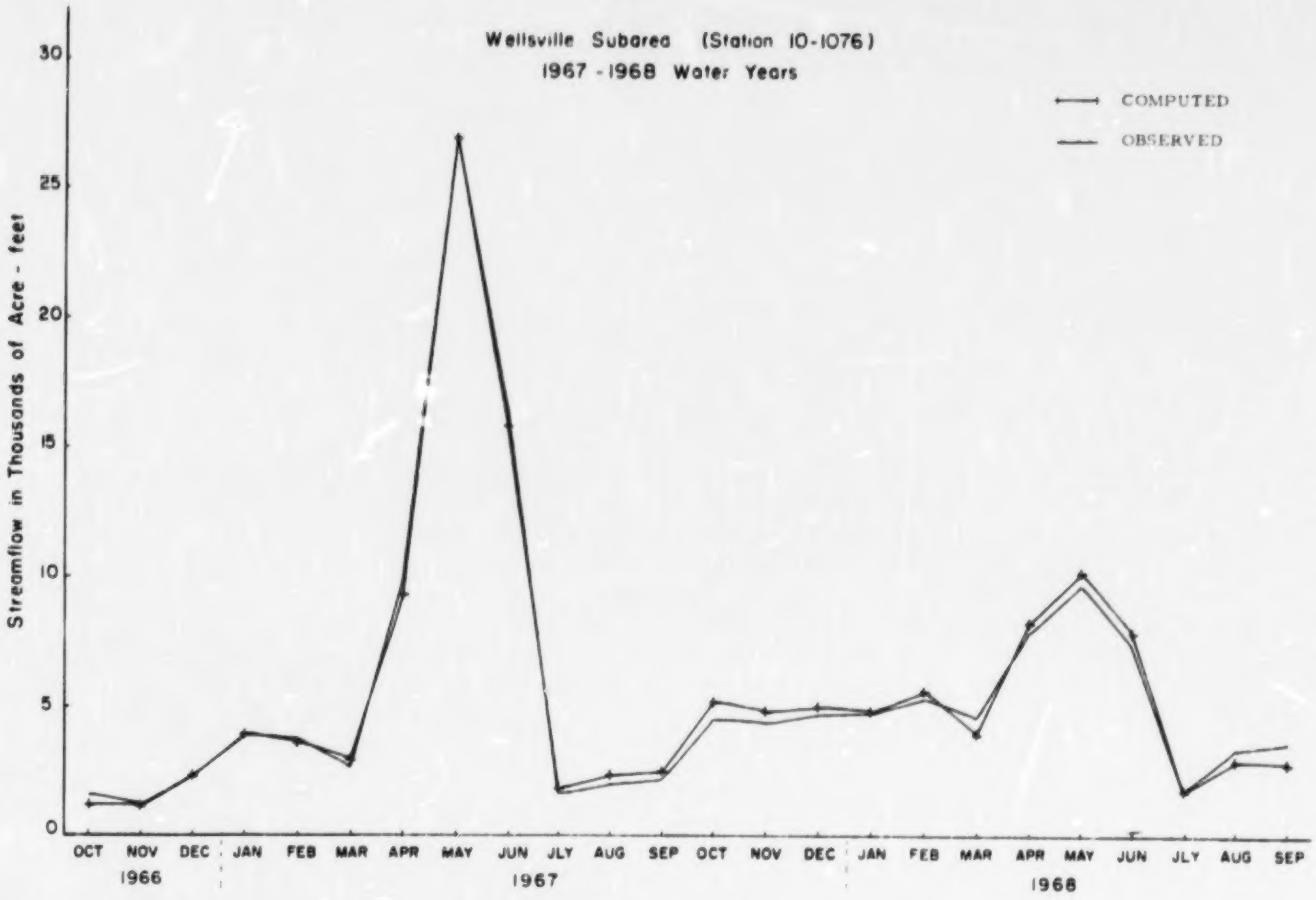


Figure 9. Gaged and computed outflows for both hydrologic subareas.

Table 2. Flow values in cfs for use in the water quality submodels.

Flow Symbol	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
							1967 Data for Paradise Subarea						
QI	28.51	29.17	31.29	31.44	32.61	78.06	172.76	421.71	246.37	85.87	50.38	40.74	104.46
QS	3.16	4.92	5.96	5.39	5.73	12.69	21.16	30.35	67.37	19.19	15.38	27.19	18.18
QGI	9.13	11.20	14.07	12.83	11.03	13.81	29.98	15.76	28.87	33.18	30.13	17.26	18.97
QD	29.88	25.01	25.00	25.00	24.99	25.00	30.00	30.01	128.88	165.09	143.30	105.71	63.37
QIR	.00	.00	.00	.00	.00	.00	.00	.00	5.32	8.58	4.59	4.10	1.89
QEF	29.99	30.01	29.99	29.99	30.00	29.99	35.01	35.00	35.01	35.00	35.00	35.01	32.51
QO	36.01	42.01	47.64	45.54	43.45	87.04	153.97	421.75	253.35	61.82	55.69	58.37	109.23
							1968 Data for Paradise Subarea						
QI	38.28	35.63	33.57	32.40	47.16	72.05	144.53	271.60	168.73	59.36	45.77	37.39	82.34
QS	4.24	6.01	6.39	5.56	8.29	11.71	17.70	19.55	46.14	13.27	13.97	24.97	14.77
QGI	17.88	16.25	16.51	10.52	30.06	29.26	7.53	5.25	38.57	37.20	48.91	29.82	23.94
QD	25.00	25.01	25.00	25.00	24.99	25.00	30.00	66.01	159.01	170.99	127.00	110.01	67.96
QIR	.00	.00	.00	.00	.00	.00	.00	.74	7.37	10.33	4.34	4.75	2.30
QEF	29.99	30.01	29.99	29.99	30.00	29.99	35.01	35.00	35.01	35.00	35.00	35.01	32.51
QO	58.27	57.37	56.58	50.04	80.32	88.61	109.31	235.84	148.34	43.10	60.92	46.08	86.24
							1967 Data for Wellsville Subarea						
QI	36.59	41.68	44.24	41.80	45.56	87.01	149.91	427.73	274.60	58.55	63.59	57.31	111.03
QS	.76	.39	1.26	2.53	.35	.35	5.57	7.53	30.30	5.50	2.19	15.64	6.00
QGI	12.02	10.73	10.27	11.61	7.81	14.89	4.43	2.60	16.17	15.22	32.83	27.44	13.88
QD	10.51	.00	.00	.00	.00	.00	.00	9.50	112.29	177.17	128.94	85.39	43.95
QIR	.00	.00	.00	.00	.00	.00	.00	.00	3.32	4.93	3.51	3.29	1.26
QEF	10.00	10.00	10.99	10.99	11.00	10.99	16.00	12.00	14.00	12.00	12.00	12.00	11.83
QO	19.60	19.42	37.61	63.88	64.67	47.71	157.12	438.24	266.69	30.36	38.59	42.07	102.26
							1968 Data for Wellsville Subarea						
QI	57.41	58.82	60.99	56.60	76.53	89.12	116.46	224.92	142.51	48.79	59.04	52.94	87.03
QS	1.02	.48	1.35	2.61	.50	.33	4.66	4.85	20.75	3.81	1.99	14.36	4.70
QGI	25.00	17.28	12.46	12.56	17.51	16.01	11.98	12.75	17.21	12.30	19.34	19.58	16.15
QD	9.76	5.04	4.88	4.88	5.40	4.88	5.04	75.35	124.53	150.92	80.98	62.00	44.74
QIR	.00	.00	.00	.00	.00	.00	.00	.00	3.50	4.24	2.20	2.45	1.04
QEF	10.00	10.00	10.00	10.99	11.00	14.00	10.00	10.00	10.00	10.00	10.00	10.00	10.50
QO	84.63	81.20	81.53	78.36	101.19	64.44	139.37	166.27	132.71	29.45	47.86	47.76	87.65

Velocity of flow has been determined for several reaches at different stages of flow by fluorescent dye techniques. Velocities associated with normal flow conditions generally averaged between 1.0 and 1.5 feet per second over reaches of 0.2 to 1.0 miles in length. The highest velocities were observed during high spring runoff, with the maximum being 5 feet per second.

The mean cross sectional area of flow for the reach was calculated from measured discharge and mean velocity. A relationship of the form

$$A_f = a\,Q^b \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (8)$$

was assumed, where A_f is the cross sectional area of flow in square feet obtained by the relationship

$$A_f = \sum^{n} d_i \cdot \Delta X_i$$

in which

d_i = mean depth at a given vertical section

ΔX_i = width of section

and Q is rate of discharge in cubic feet per second. The a and b were essentially 2.0 and 0.7 at all reaches investigated.

Average stream width was also measured or estimated from high water marks. Mean stream depth was then calculated and regressed against rate of discharge, assuming an exponential equation:

$$d = a'Q^{b'} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (10)$$

Again, the a and b were practically the same for all reaches. Here the approximate values were taken as 0.2 and 0.6 respectively.

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CHAPTER IV

SALINITY SUBMODEL

Dissolved mineral concentration (salinity) is an important measure of water quality, particularly for irrigated agriculture and, in some cases, for municipal and industrial water supplies. Specific electrical conductance (hereafter referred to as EC) is used as the salinity indicator because: (1) it is easily and accurately determined; (2) it is a better index of total ionic activity of dissolved salts than is a total dissolved solids (TDS) rating; and (3) the TDS test, as outlined in Standard Methods (American Public Health Association, 1965) may, in certain cases, result in significant diminution of dissolved mineral weight by volatilization of carbon dioxide (U.S. Salinity Laboratory Staff, 1954).

Electrical conductance was simulated by first developing relationships between EC and flow for each hydrologic input and then combining these inflows at the upstream end of the reach to yield a weighted average conductivity value for that reach. No "in-transit" equation is required, as conductance is a conservative water quality parameter.

Input conductances

As shown in Figure 2, the inflow to any reach (i) is composed of one or more of six inflow components: outflow from the reach immediately upstream on the same branch ($Q_{i+1,j}$); outflow from river branches which are tributary to the reach being studied ($QBR_{i,j}$); other natural surface inflow to the reach ($QS_{i,j}$); surface irrigation return flow ($QIR_{i,j}$); groundwater inflow ($QGI_{i,j}$); and municipal and industrial releases ($QEF_{i,j}$). The conductance of each of these hydrologic inputs must be determined to permit evaluation of the conductance of the combined flow.

Reach inflow

The conductance of the outflow from the upstream reach is taken as that resulting from the simulation of the upstream reach.

Branch inflow

Here again, the conductance is taken as that previously found for the tributary branch.

Surface inflow

Analysis of project data indicates that the conductance of natural diffuse surface waters is closely related to rate of flow. Coefficients of correlation range from .69 to .90 (Figures H-4, H-5, and H-6). These orders of magnitudes were supported in the review of published literature on the subject. Although the literature in this area is somewhat sparse, researchers have long recognized the relationship between salinity and rate of flow. In fact, Lentz and Sawyer (1944) attempted to estimate flow rates from salinity data for streams in the Madison Lakes area.

In what is generally regarded as the pioneering work in this field, Durum (1953) established that chloride concentrations in the Saline River, Kansas, were inversely related to flow. He found that the total salt load (salinity times flow rate) was nearly constant, though it did tend to be slightly higher during periods of high flow.

Extending on the work of Durum and using data from the Arkansas and Red Rivers, Ward (1958) proposed an exponential relationship of the form

$$S = a \cdot Q^b \quad \dots\dots\dots (11)$$

in which

S = salt concentration
Q = rate of flow
a and b = constants

Ledbetter and Gloyna (1964) extended the simple exponential model advanced by Ward by allowing "b" to vary with rate of flow, according to the relationship

$$b = p \cdot Q^s \quad \dots\dots\dots (12)$$

in which
b = exponent for Equation 11
Q = rate of flow
p and s = constants

As an alternate to this relationship, especially applicable with reference to rivers of the arid southwest, they suggest that "b" be related to current rate of flow and antecedent flow conditions by the equation

$$b_k = f + g \cdot \log (Aq_k) + h \cdot Q_k^{s} \quad . . (13)$$

in which
b_k = exponent for Equation 10
Aq_k = antecedent flow index $\left(\sum_{d=1}^{30} \right) \frac{Q_d}{d}$
d = the number of days, counted back from the "k th" day
Q = rate of flow
f, g, h and s = constants

Ledbetter and Gloyna, Hart, King, and Tchobanglaus (1964) state that they have adequately represented changes in the salinity of the Russian River of northern California by breaking the total flow of the river into its component parts:

$$S = a_1 \cdot q_g^{b_1} + a_2 \cdot q_i^{b_2} + a_3 \cdot q_s^{b_3} \quad . . (14)$$

in which
S = salt concentration
q_g = the groundwater component of flow
q_i = the interflow component of flow
q_s = the surface contribution to flow
a_i and b_i = constants

Gunnerson (1967) in a study of Columbia River data found that variation from the exponential prediction equation of Ward (Equation 11) tended to follow a seasonal elliptical donut pattern; with winter and spring values generally plotting above the prediction line and summer and autumn points below. Each sampling point examined had a unique variation pattern.

In addition to the models outlined above, a simple semi-log relationship of the form

$$S = a + b \cdot \log Q \quad . . . . . . (15)$$

in which
S = salinity
Q = flow rate
a and b = constants
was fitted to the data.

The more complex relationships (Equations 12, 13, and 14) failed to demonstrate any significant improvement over the simple exponential and semi-log relationships in fitting data available from the current project. Ward's exponential formulation (Equation 11) fit the data slightly better than did Equation 15, the semi-log form. The values of the constants "a" and "b," as determined by least squares fitting of Equation 11 are given in Table 3, along with the coefficients of determination for several of the sampling points in the Little Bear River system. The constants a and b may vary considerably within the stream system, as illustrated in Table 3; data upon which Table 3 is based are from the period June 1966 to December 1967.

Table 3. Relationship of electrical conductance to rate of discharge on the Little Bear River system. (EC = a Qb)

Station	a (constant)	b (constant)	R^2[b] (%)
S-12.5	1000	-.16	66.
S-15.2	505	-.06	47.
S-27.0	815	-.34	92.
S-27.5	781	-.31	84.
SD-0.0	568	-.17	69.
SEC-6.2[a]	363	-.002	00.

[a] Data were taken only during periods of relatively low flow due to access problems during the spring high water period.

[b] Percent of total squared variation in the dependent variable explained by the model.

Figure 10 is a log-log plot of conductance vs. flow rate for data obtained from station S-27.0, for the period June 1966 to June 1967. Equation 11 is plotted also with constants determined by least squares regression analysis of data.

Irrigation return flow

On the average, about one-third to two-thirds of the water diverted for agricultural irrigation is used consumptively. The remainder finds its way back to the resource pool as deep percolation to groundwater, overflow from the distribution system, or surface runoff from irrigated fields (McGauhey, 1968).

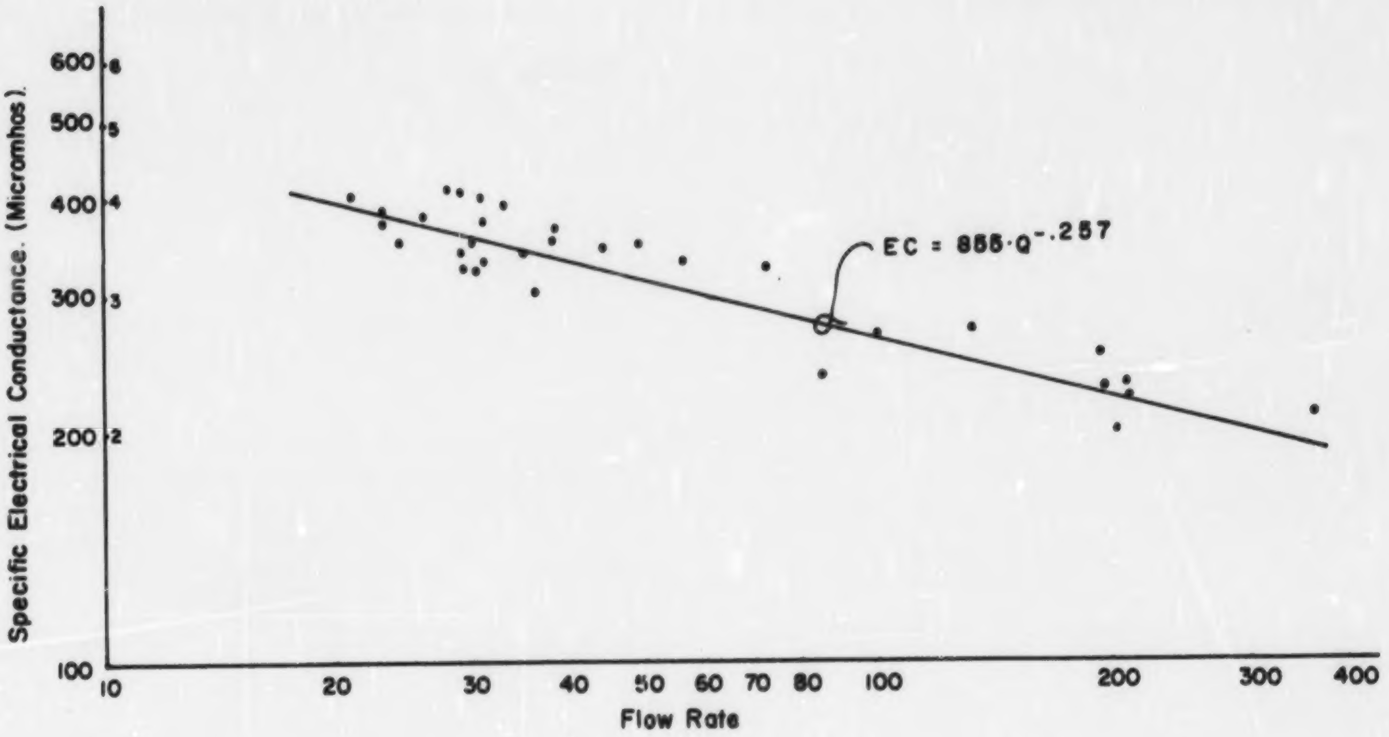


Figure 10. Specific electrical conductance vs. discharge for station S-27.0 on the Little Bear River.

Eldridge (1963) states that "return flows from irrigation projects contain at least three, and often as high as ten times the concentration of mineral salts as that of the initial irrigation water." The Utah State University Foundation (1969) suggests that a more realistic range of salinity multipliers might be two to seven. Undoubtedly, the highest concentrations occur in the percolating segment of the return, as this will carry with it a portion of the soil solution in which the salinity has been increased by transpiration, as well as any salts leached from the soil profile.

For purposes in this study, the deep percolating portion of the return flow is assumed to be included in groundwater; thus the salinity multipliers have automatically been restricted to the low end of the range mentioned above. A multiplier of approximately two has been assumed. This value is lower than mentioned in the literature, but seems to be more consistent with project data. This is supported particularly by comparing data from groundwater sampling point U-2510, as shown in Table 4, with conductance values of irrigation waters which are on the order of 300 to 400 μ mhos/cm.

Groundwater inflow

Four groundwater sampling points have been established along the Little Bear River system. These sampling points include one natural spring, an improved spring, an artesian well, and a field drain.

Although the data for individual sampling points showed considerable scatter, no significant variation occurred with time of year. Considerable differences were observed between sampling points (Table 4). On the basis of this information, constant electrical conductance levels have been assigned to groundwater inflow to a given reach. The value assigned varies from reach to reach, in conformance to the tendencies disclosed in Table 4.

Municipal and industrial releases

The characteristics of municipal and industrial wastes are highly variable. Industrial wastes, however are highly specific to the type of industry from which they derive. The most logical approach to the simulation problem is to require data inputs to define the quantity and quality characteristics of each effluent being discharged into the stream system.

Stream conductance

Equation 16 calculates the conductance for reach i by the weighted average of all flow inputs for that reach. Stated algebraically:

Table 4. Electrical conductance at groundwater sampling points.

Sampling point	Number of Samples	Location	Description	Ave. (µmhos/cm)	Range (µmhos/cm)
U-2311	12	north of Wellsville	artesian well	576	340-715
U-2510	11	east of Wellsville	field drain	732	650-900
U-2907	11	south of Hyrum	improved spring	652	515-790
U-3198	10	west of Avon	natural spring	409	310-520

$$\begin{aligned} EC_i = (&EC_{i+1} \cdot Q_{i+1} + ECBR_i \cdot QBR_i \\ &+ ECS_i \cdot QS_i + ECIR_i \cdot QIR_i \\ &+ ECGI_i \cdot QGI_i + ECEF_i \cdot QEF_i)/(Q_i \\ &+ QD_i) \quad \ldots\ldots\ldots\ldots\ldots (16) \end{aligned}$$

in which

Q_{i+1}, QBR_i, QS_i, QIR_i, QGI_i, QEF_i, Q_i, and QD_i are all as previously defined and

EC_i = electrical conductance of reach "i" outflow

EC_{i+1} = electrical conductance of outflow from the adjacent upstream reach on the same branch

$ECBR_i$ = electrical conductance of outflow from a branch tributary to reach "i"

ECS_i = electrical conductance of surface inflow

$ECIR_i$ = electrical conductance of irrigation returns

$ECGI_i$ = electrical conductance of groundwater inflow

$ECEF_i$ = electrical conductance of municipal and industrial discharges

In-transit conductance changes

Because salinity (and thus electrical conductance) is a conservative parameter of water quality, (ignoring possible precipitation reactions), no changes in level result from the passage of time or distance covered. The conductance at the lower end of a reach is taken to be the same as that at the upper end, after mixing inflow components.

Reservoir routing

Reservoir inflows are combined with waters of different levels of conductivity carried over in storage from previous time periods. Complete mixing of these inflows with reservoir contents has been assumed, even though stratification and/or short circuiting may tend to prevent it. This simplification was invoked because of the lack of detailed data on the variation of density and conductivity within the impoundment. Employing the principle of mass balance, the conductivity of storage carried over into the next time period may be shown to be

$$ECST_{k+1} = \frac{2(VST_k \cdot ECST_k + VIN_k \cdot ECIN_k) - VOUT_k \cdot ECST_k}{VOUT_k + 2 \cdot VST_{k+1}} \quad \ldots\ldots\ldots\ldots (17)$$

in which

ECST = the electro-conductivity of water stored in the reservoir at the beginning of time period k

VST = the volume of water stored in the reservoir at the beginning of time period k

VIN = the volume of inflow to the reservoir during time period k

ECIN = the electro-conductivity of this inflow as determined by Equation 16

$VOUT_k$ = the volume of reservoir discharge during time period k

There are two assumptions implicit in Equation 17. First, the contents of the reservoir will be completely mixed so that the salt concentration in reservoir discharges will be the same as the average concentration of dissolved solids in the reservoir. This assumption may not be valid for time periods of short duration or for deep, thermally stratified bodies of water. Second, precipitation of calcium carbonate is not significant.

Simulation algorithm

The various elements of the electrical conductance submodel are integrated by a simulation algorithm which comprises the submodel.

Briefly, the simulation algorithm for monthly stream conductivity, for a given reach, consists of the following procedure, which is outlined also in Figure 11.

1. Obtain hydrologic input flows for each reach for each monthly time period of interest using hydrologic submodel.
2. Establish, by regression analysis using field data, the constants a and b for Equation 15, for appropriate hydrologic flow inputs.
3. Define salinity by card input for flows not amenable to Equation 15 application.
4. If reach is a reservoir, use Equation 17, which mixes over two time periods.
5. Apply Equation 16 to all reach inputs to obtain reach salinity.
6. Go to next reach and repeat procedure beginning with step 1.
7. Go to next time period beginning with step 1.

The procedure for computer simulation of the above algorithm is described in Appendix E, where it is incorporated into the WAQUAL main program as the subprogram ELCON. Steps 3, 4, 5 are done by ELCON; steps 1, 6, and 7 by the system control model, and step 2 is done by the user, prepartory to simulation.

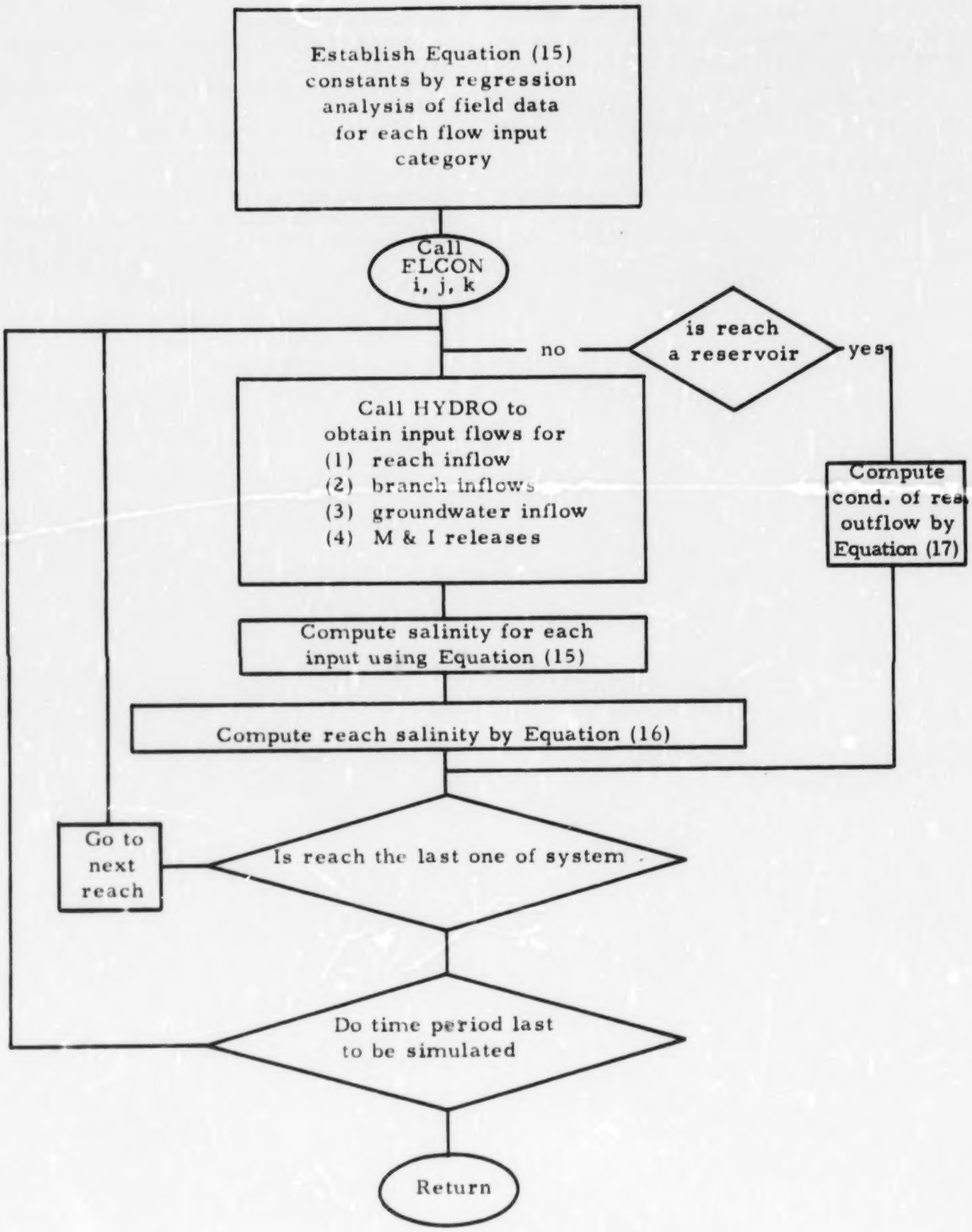

Establish Equation (15) constants by regression analysis of field data for each flow input category
Call ELCON i, j, k
no
is reach a reservoir
yes
Call HYDRO to obtain input flows for
(1) reach inflow
(2) branch inflows
(3) groundwater inflow
(4) M & I releases
Compute cond. of res outflow by Equation (17)
Compute salinity for each input using Equation (15)
Compute reach salinity by Equation (16)
Go to next reach
Is reach the last one of system
Do time period last to be simulated
Return

Figure 11. Simulation algorithm for electrical conductance submodel.

CHAPTER V

STREAM TEMPERATURE SIMULATION

The temperature problem

The factor of stream temperature has evolved only recently to a perspective commensurate with its environmental effects. This is partially because the current and projected magnitudes of the temperature problem are such that it cannot be ignored. In 1964 the cooling water intake by industries amounted to 50,065 billion gallons (FWPCA, 1968). The U.S. Senate Select Committee on National Water Resources in 1960 projected cooling withdrawals of 576 billion gallons per day by 2000.

Thermal pollution, as it is now called, exerts a profound influence upon the receiving water body. First, the direct and indirect effects on the biotic communities may in some instances be quite severe. The ecology of the water body may be changed entirely. Decreased oxygen solubility, increased oxygen demand, increased growth of some algae species, and increased toxicity to some substances are some of the peripheral synergistic effects. The mutual effects upon other cooling water users, and the change in palatability of the water for municipal use are among a few of the many additional considerations.

A natural stream will exhibit temperature behavior characteristics in both time and space, and these can have a significant bearing upon its reaction to thermal discharges. These characteristics include: (1) a diurnal temperature variation in the stream, (2) an annual cycle of mean daily stream temperatures, and (3) an in-transit decay of any point imposed temperature differentials. These characteristics are, of course, because the stream water body is virtually never at temperature equilibrium with its surroundings; thus the problem is one of heat transfer. Therefore, all of the factors relevant to heat transfer are pertinent to the problem of temperature behavior of a stream. These factors include: (a) size of stream, (b) turbulence characteristics of the stream, (c) solar insolation, (d) atmospheric turbulence, (e) temperature differential between the atmosphere and stream water body, and (f) mass inputs of new water. Inclusion of these factors is necessary to a rational comprehensive modeling treatment.

This comprehensive approach would not necessarily fit the philosophy of the project objective, however, which was to find a way to simulate the three effects listed above in the most pragmatic manner possible. The law of heat transfer is the basis for the empirical approach also, but applied in an empirical manner. In essence atmospheric temperatures (obtained from weather station records) are matched against corresponding stream temperatures and the stream temperature response is thus "calibrated." Obviously this method is gross as all of the many independent variables of heat transfer are absorbed and integrated in a single coefficient. Nevertheless it works and is empirically feasible—which is the principal objective.

The simulation procedure was divided into two basic phases: (1) computer simulation of mean monthly water temperature by a program called WATEMP, and (2) computer simulation of diurnal water temperature for each month, by a program called DITEMP. Each of these basic algorithms considers: (1) the time variations in temperature of all hydrologic mass inputs-discrete and diffuse, (2) in-transit changes within a reach, and (3) the effect of reservoirs.

Monthly water temperature simulation

The monthly temperature simulation model (WATEMP) accomplishes three tasks. First, it can simulate the mean monthly stream temperature through the annual cycle. Second, it can simulate the stream in-transit response to any imposed heat load. And third, it can call up the diurnal submodel, DITEMP (by means of WAQUAL). This section describes the equations used and how they operate to accomplish these tasks.

Temperature simulation of reach inputs

Each hydrologic input to a river reach has a unique pattern of temperature variation with time. Alternative methods of representing these variations for each input are outlined below. After each input temperature is simulated the weighted average of inputs equates with the temperature at the upstream end of the reach (Equation 16 applies).

River inflow. The simulation procedure begins at the upper extremity of each branch, and proceeds in a downstream direction. Results from the simulation of the adjacent upstream reach are always available as an input for the simulation of the next reach downstream. For the first reach analyzed on a branch, the stream inflow is assumed to be zero and all natural surface inflows are lumped together in the "surface inflow" category (QS). The method of approximating the temperature of this component is discussed below.

Branch inflow. Branches tributary to a reach are simulated before the reach is analyzed. The temperature of inflow from tributary branches is therefore available for incorporation into the analysis.

Surface inflow. The temperature of inflowing diffuse surface waters follows a sinusoidal pattern through the annual cycle. Superimposed upon this annual variation, there is a diurnal cycle, discussed in detail in the section following. Figure 12 illustrates the sinusoidal variation of water temperature through the year. Measured water temperatures have been adjusted to mean daily values to remove the influence of diurnal fluctuations.

Ward (1963) fitted a sine curve of the form

$$\bar{T} = \bar{\bar{T}} + C \cdot \mathrm{Sin}\left(\frac{2\pi}{365} \cdot x + A\right) \quad \ldots \quad (18)$$

to temperature data from unheated natural streams by least squares procedures in which

$\bar{T}$ = mean daily stream temperature

$\bar{\bar{T}}$ = mean annual stream temperature

x = day of the year after October 1

The terms C and A are, respectively, a constant and a phase shift angle determined by least squares analysis. Ward found this model to fit temperature data well with little between-years variation in model constant and phase shift. Jaske (1968) employed the same method of characterizing annual water temperature variations in his study of the temperature characteristics of the Columbia River.

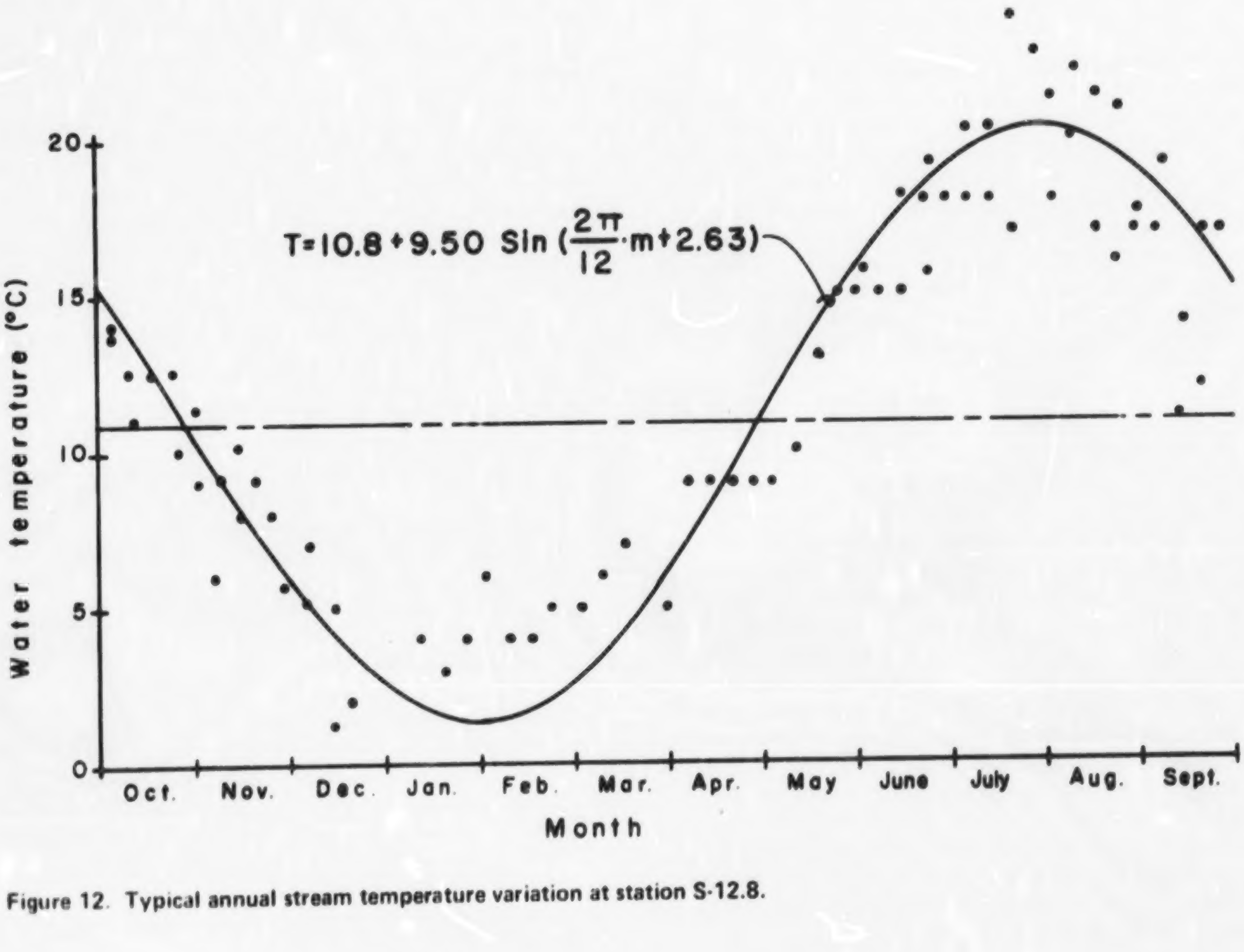


Figure 12. Typical annual stream temperature variation at station S-12.8.

Table 5 shows the results of applying Equation 18 to temperature data from the Little Bear River. The fit of Equation 18 to the data, as measured by the coefficient of determination (R^2), is consistently high at all but one of the twelve sampling points. The station for which the poor fit was obtained is the one designated SEC-4.3, located immediately downstream from the Porcupine Reservoir outlet works. Expanding Equation 18 into two and three-term Fourier series did improve the fit at this station (but not at the other stations).

Utilization of the procedure outlined above requires a record of stream temperatures at the point in question. Observations should be taken at least weekly over a period of one or more years. As noted in Table 5, data from the Little Bear River system indicate that the constant C and the phase shift angle A do not differ greatly from one station to another in the system, if the waters being compared are of the same basic make-up, i.e., have about the same proportions of groundwater at the two points, etc. It should be possible then, if judgment and discretion are exercised, to transfer these two coefficients from one station to another within a small hydrologic system.

A major disadvantage of the Equation 18 approach is that it ties water temperature directly to time of year, rather than to atmospheric temperature. This hinders the assessment of the effect of stochastic variations in monthly atmospheric temperature upon stream temperature. In addition, at least one complete cycle of stream temperature data is required to adequately determine the sine curve parameters.

Another approach in the modeling of surface inflow temperatures, is to correlate stream temperature and atmospheric temperature. Where the modeling increment is one month, the monthly average of atmospheric temperature can be used to estimate mean monthly stream temperatures. Intervals shorter than one month, however, would require that antecedent atmospheric temperatures be considered.

Monthly averages of stream temperatures, adjusted to mean daily values, have been regressed against mean monthly atmospheric temperatures from the Logan USU Weather Bureau station located about ten miles north of the project area. A linear equation of the form

$$\overline{T} = a + b \cdot \overline{T}_a + \varepsilon \; . \; . \; . \; . \; . \; . \; (19)$$

is assumed in which

$\overline{T}$ = mean monthly water temperature (°C)
$\overline{T}_a$ = mean monthly atmospheric temperature (°F)
ε = deviation of observed water temperature from predicted values
a and b = regression constants

Equation 19 is a desirable alternate because it more clearly portrays the cause-effect relationship responsible for changes in stream temperature. It should also be possible to satisfactorily define the coefficients for this equation with something less than a full annual cycle of data as long as the temperature measurements cover a period including both high and low stream and atmospheric temperatures. The results of applying Equation 19 to data from 14 water quality sampling stations are tabulated in Table 6.

Table 5. Representation of annual changes in mean daily water temperature.

$$\left[\overline{T} = \overline{\overline{T}} + C \cdot \mathrm{Sin}\left(\frac{2\pi}{365} \cdot x + A\right)\right]$$

Station	$\overline{\overline{T}}$ (°C)	C (constant)	A (radians)	R^2 (%)	Comments
S-12.7	10.7	7.135	2.675	88.	
S-12.8	10.8	9.505	2.630	90.	
S-15.2	10.5	9.102	2.573	92.	
S-16.8	10.2	14.477	2.515	88.	reservoir surface
S-21.3	8.7	7.209	2.659	90.	
S-24.6	8.7	7.466	2.663	87.	
S-27.5	9.4	6.565	2.670	85.	
SD-0.0	7.8	8.652	2.674	85.	
SEC-4.3	8.3	11.208	2.068	71.	reservoir outflow
SEC-6.2	7.1	7.288	2.604	85.	
SW-0.1	11.2	5.278	2.684	83.	largely spring fed
STF-0.0	8.8	6.977	2.653	86.	trout farm discharge

Table 6. Prediction of stream temperature from atmospheric temperatures. ($T = a + b\,T_a$)

Station	a (constant)	b (constant)	R^2 (%)	Notes
S-12.7	-4.09°C	.310	97.	
S-12.8	-7.53	.387	93.	
S-15.2	-6.90	.373	93.	
S-16.8	-10.22	.475	88.	reservoir surface
S-21.3	-6.01	.312	95.	
S-24.6	-5.92	.310	94.	
S-27.0	-5.90	.308	93.	
S-27.5	-2.24	.252	93.	
SD-0.0	-8.77	.356	95.	
SEC-0.4	-5.08	.295	90.	
SEC-4.3	-1.75	.211	57.	reservoir discharge
SEC-6.2	-5.10	.270	71.	
SW-0.1	0.63	.221	87.	largely spring fed
STF-0.0	-5.54	.304	94.	

Table 7. Annual temperature variations of groundwater.

$$\left[\bar{T} = \bar{\bar{T}} + C \cdot \mathrm{Sin}\left(\frac{2\pi}{365}x + A\right)\right]$$

Sampling point	$\bar{\bar{T}}$ (°C)	C (Constant)	A (radians)	R^2 (%)	Description
U-2311	10.5	1.519°C	2.367	58.	artesian well
U-2510	10.5	2.706	1.892	91.	field drain
U-2907	11.4	1.419	2.230	55.	improved spring
U-3198	10.8	1.993	2.239	87.	natural spring

Again, a degree of consistency was noted in the relationships between air and water temperatures at all stations except those at which the stream is affected by reservoirs or proportionately large groundwater contributions. The coefficients of determination (R^2) are uniformly high, except at two stations on the East Fork of the Little Bear River (SEC-4.3 and SEC-6.2). At station SEC-4.3 the flow is composed almost entirely of waters released from Porcupine Reservoir. These releases do not correlate well with atmospheric temperature. No explanation has been found for the relatively poor fit at SEC-6.2 which is upstream from Porcupine Reservoir.

Comparing the R^2 values in Tables 5 and 6, Equation 19 would appear to be a slightly better fit than Equation 18. Equation 19 also has the advantage of being based upon mean monthly air temperature and therefore Equation 19 was used.

Irrigation return flow. Surface return flows from irrigation are also assumed to be linearly related to atmospheric temperature as described by Equation 19. Because temperatures of these flows were not measured, it has been necessary to assume values for the model constants.

Eldridge (1963) suggests that the contributions of irrigation return flows to the thermal behavior of a stream are of minor importance. In considering surface return flows, it was assumed that such flows are warmer than natural surface inflows. Equation 19 was adopted to simulate the temperature behavior of return flows. Because temperatures of these flows were not measured, it has been necessary to assume values for the Equation 19 constants.

Groundwater inflow. Table 7 gives the results of fitting groundwater temperatures at four groundwater sampling points in the project area to Equation 18. Although the determination coefficients for the artesian well and the improved spring are not good, the seasonal variation in temperature at these points is significant. At these two locations, the small proportion of the total variation explained by the seasonal model is probably due to the relatively great depths at which the flows originate. Because no distinction has been made in the simulation program as to the depth from which groundwater originates, the prediction model used is a composite of those obtained from the four sampling points.

Municipal and industrial releases. The thermal qualities of municipal and industrial waste waters discharged to the stream must be provided as a data input for each simulation run of the model.

In-transit temperature changes

The temperature of a moving body of water is subject to many influences along its course. Solar radiation and atmospheric convection tend to increase the temperature during daylight hours, while evaporation and other phenomena tend to decrease it. Until recently, relatively little work has been published concerning this important process in natural streams.

The American Society of Civil Engineers Committee on Thermal Pollution (1967) has assembled an extensive bibliography on thermal pollution. Publications listed in this bibliography, and other published material on this topic, fall generally into three classifications: (1) the occurrence of thermal pollution; (2) the effects of thermal pollution upon the aquatic environment ; and (3) temperature prediction in natural and thermally polluted bodies of water. The latter class is notable for the relatively small number of contributions.

Most of the early work on temperature prediction techniques was done on cooling ponds and reservoirs. The first of these studies was by Ruggles (1912). Subsequent investgations were performed by Lima (1936), Thorne (1951), Langhaar (1953), and others.

The initial work on stream temperature prediction was published by LeBosquet (1946). He assumed an exponential decay of warm water toward the prevailing air temperature. His derived relationship was of the form

$$\Delta\overline{T}_2 = \Delta\overline{T}_1\cdot e^{\left(-\frac{.0235\cdot k_e\cdot w}{Q}\cdot H\right)} \quad . . (20)$$

in which

$\Delta\overline{T}_1$ = "excess" temperature of water over air at the initial point "1" (°F)

$\Delta\overline{T}_2$ = "excess" temperature of water over air a distance "D" miles downstream from the initial point "2" (°F)

k_e = heat loss coefficient (BTU/sq. ft./hr./°F of "excess" temperature)

w = average stream width (ft.)

Q = average discharge (cfs)

H = mean stream depth (ft.)

LeBosquet found values of the heat loss coefficient ranging from 6 to 18 BTU/sq. ft./hr./°F (0.2 to 0.6 ft./hr.).

This technique has been criticized on two counts. First, values of the heat loss coefficient must either be guessed or calculated from measurements after the thermal pollution has occurred. It would seem that this difficulty could be partially mitigated by experimental analysis. The second question concerns the assumption that in the absence of thermal pollution, air and water temperatures would tend to be equal. Although air temperature is an important factor in determining the temperature of a body of water, other variables, such as evaporation, back radiation, etc., tend to lower the "equilibrium" temperature of the stream below atmospheric temperature.

Gameson, Hall, and Preddy (1957) used essentially the same approach as that advocated by LeBosquet to analyze the thermal characteristics of the Thames estuary. They avoided the second criticism of LeBosquet's model by using temperature excess above some "equilibrium" water temperature instead of the excess of water temperature over air temperature. From estimated rates of heat addition by urban and industrial developments along the estuary, they estimated the coefficient of heat loss at 4.0 centimeters (0.13 feet) per hour. For the River Lea, Gameson, Gibbs, and Barret (1959) found heat loss coefficients, averaged over four days for four different reaches, to range from 1.66 to 3.83 cm/hr. (.054 to .126 ft./hr.). The overall average for the river was 2.6 cm/hr. (.085 ft./hr.).

Recent work has been directed to the heat-budget analysis approach. Among those contributing to the literature on this topic are: Velz and Gannon (1960), the Johns Hopkins Advanced Seminar (1961), Edinger and Geyer (1965), Edinger, Brady, and Graves (1968), and others. The heat-budget method requires data on solar radiation and wind velocities which are not generally available. No data of this nature were taken during this project so the heat-budget approach was eliminated from consideration for purposes of this work.

Duttweiler (1963) has developed a procedure, wherein the exponential decay theory is employed with "equilibrium" temperatures and heat exchange coefficients being estimated from heat-budget considerations. This is a rather rigorous approach which would seem to possess certain merit as a modeling technique. However, for application to the data available from the current project it was of limited usefulness because of the lack of more detailed climatological data such as windspeed and radiation.

The simulation procedure finally adapted for this work satisfied the pragmatic criteria of reliability and data availability. This procedure involved the LaBosquet Equation 20, for predicting decay of temperature excess, in conjunction with Equation 19 for assessing stream equilibrium temperature. Equation 19, which gives mean monthly stream temperature, was felt to be as reasonable estimate of equilibrium temperature as feasible.

In mathematical form, the complete model for a nonreservoir reach is

$$\overline{T}_2 = \left(\frac{\sum_{j=1}^{nc} q_j\cdot\overline{\tau}_j}{Q} - E_1\right)\cdot e^{-\phi} + E_2 \quad . . . . (21)$$

in which

q_j = rate of flow for input j

$\overline{\tau}_j$ = mean monthly temperature of input j

$Q = \sum_{j=1}^{n} q_j$

nc = number of hydrologic inputs to the reach

$\overline{T}_2$ = mean monthly stream temperature at the downstream end of the reach

E = "equilibrium" temperature

$\phi = \frac{.0235\cdot k_e\cdot w}{Q}\cdot D$

In Equation 21, the subscript 1 indicates the upstream end of the reach, while 2 denotes the downstream end. All flows and temperatures are monthly averages for the month of simulation. Mean monthly input temperatures, $\overline{\tau}_j$, are estimated according to the equations shown in Table 8.

Table 8. Summary of mean monthly temperature equations for hydrologic inputs.

Input	Model
River inflow	output from previous simulation
Branch inflow	output from previous simulation
Surface inflow	$\overline{T}_s = a + b\cdot T_a$
Irrigation return flow	$\overline{T}_i = a + b\cdot T_a$
Groundwater inflow	$\overline{T}_g = \overline{\overline{T}}_g + C\cdot \mathrm{Sin}\left(\frac{2\pi}{12}\cdot m + A\right)$
M & I releases	card input

Heat exchange constants for streams of this system were approximated from the river reach downstream from Porcupine Reservoir. During the summer irrigation season, releases from the reservoir originate in the cold hypolimnetic zone, resulting in significant temperature deficits at the reservoir outlet. The rate at which these deficits approach zero, as these cold waters are warmed toward the "equilibrium" temperature in the reach below the reservoir, was employed in the evaluation of the heat exchange constant, k_e.

On seven different days during the summer of 1968, temperature observations were made at the outlet from Porcupine Reservoir and at Avon, 3.9 miles downstream. Temperature deficits (ΔT_1 and ΔT_2) were taken as the difference between temperatures observed at the points in question and those measured at nearby sampling points not affected by reservoir releases, respectively. These deficits were then inserted into Equation 20, the exponential decay expression, which was solved for k_e. Values obtained are compared with those reported by other researchers in Table 9. A heat exchange constant of 0.20 has been assumed in the development of the present model. Provision is made to allow this "constant" to vary with rate of discharge, according to a hypothetical relationship of the form

$$k_e = a\cdot Q^b \quad . . . . (22)$$

Because of the dearth of data here and the lack of a significant source of thermal pollution on which to test a prediction equation, a constant level for the exchange coefficient is all that is justified.

Table 9. Heat exchange coefficients.

Researcher	Min. (ft./hr.)	Max. (ft./hr.)	Water body
LeBosquet (1946)	0.2	0.6	
Gameson et al. (1957)		0.13	Thames estuary
Gameson et al. (1959)	0.054	0.13	River Lea
Duttweiler (1963)	0.047	0.15	Winter's Run
Edinger et al. (1968)		0.12	Cooling pond
Current research	0.09	0.40	Little Bear River

Adjustment of discrete sampling data

As depicted in Figure 19, temperatures during the 8:00 a.m. to 5:00 p.m. working day, when samples were gathered, vary over a large part of the amplitude of the diurnal fluctuation. Because temperatures were not measured at the same time at each sampling point, a more or less random appearing error was introduced into the data. Had a rigid time schedule been followed, so that each site was always visited at the same hour, the diurnal effect would have imparted a systematic downward bias for those points sampled early in the day, while those sampled later in the day would have been biased upward.

To isolate the diurnal component of variation, the model of diurnal fluctuations (called DITEMP and discussed in the following section) was utilized. By employing the diurnal model to adjust all descrete temperature data to mean daily values, it was possible to achieve considerable improvement in the fit of the inflow temperature prediction relationships over that resulting from the use of unadjusted data. Consequently, all stream temperatures, obtained by discrete measurement, have been adjusted to mean daily stream temperature.

Reservoirs

The primary effect of impoundments on downstream temperatures is that of cooling during summer irrigation months if, as is true in the case of Porcupine Reservoir, releases are discharged from the hypolimnion directly into the stream channel below the dam. Temperature data from station SEC-4.3, below Porcupine Dam, are shown in Figure 13. These data have not been adjusted for diurnal effects because the deep waters of the hypolimnion are not subjected to diurnally varying factors. As a result, temperatures in this zone are constant through the diurnal cycle.

These data fit nicely into a theory presented by Churchill (1965) in which he considers the reservoir as being thermally stratified during summer months. He assumes the outlet works to draw only from a relatively thin layer at the depth of the discharge, so that during the irrigation season coldest waters are released first. Released water temperatures gradually increase as the reservoir level recedes and the warm upper layers fall to the level of the discharge opening. Although temperature data available for the station below Porcupine Reservoir indicate that this procedure would apply, it has not been employed because its application requires a complete thermal map-

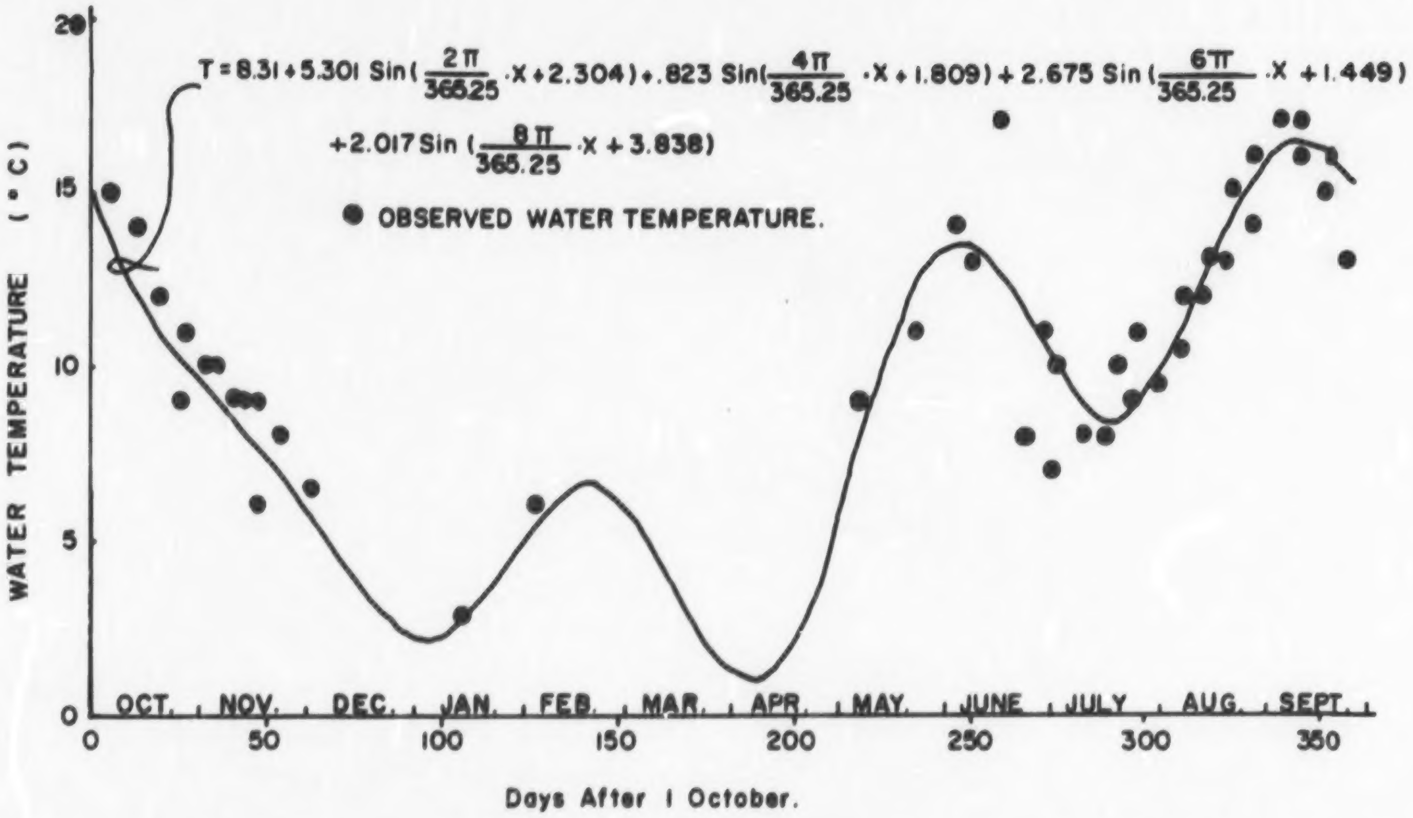


Figure 13. Annual stream temperature variation at SEC-4.3 below Porcupine Reservoir with best fit four-term Fourier series curve.

ping of the reservoir each spring to define the temperature-depth profile throughout the reservoir at the beginning of the irrigation season. Such a survey was beyond the scope and economic resources of this project.

The procedure finally adopted is that of obtaining a temperature record for reservoir releases covering at least one full year and fitting a four term Fourier series model

$$\overline{T} = \overline{\overline{T}} + \sum_{j=1}^{4} C_j \operatorname{Sin}\left(\frac{2\pi}{365} j\cdot x + A_j\right) \quad . (23)$$

to the data, as outlined in Appendix D. The best fit Fourier series prediction is shown in Figure 13, superimposed on the observed temperature of released waters. The lack of data during winter and spring months, caused by difficult access during this period, allowed the Fourier series best-fit curve to drop again in early spring. This would not be expected in actual field observation. Had data been available for this time of year, the curve would have been forced to follow the data, rather than being free to take the path of least resistance.

The curve-fitting approach means, of course, that unless more than one year's data are available, data from that year must be accepted as representative of all years of data. This may be a serious limitation if the operating procedures for the reservoir are subject to significant change from year to year.

Algorithm for simulation

Figure 14 outlines the simulation algorithm for monthly stream temperature and this algorithm also is summarized below.

1. Obtain monthly flow values for all inputs from hydrologic model.
2. Establish constants a and b in Equation 19 for each inflow by regression analysis of data.
3. Compute temperature of each input to reach for month in question using Equation 19—where applicable; otherwise define flow input temperature by punched cards; use Equation 18 for shallow groundwater inputs.
4. Compute stream temperature, consisting of combined inflows, using Equation 16.
5. If reach is a reservoir apply Equation 23 to obtain temperature of outflow and simulate next reach beginning with step 1 again.
6. For non-reservoir reaches, if a "temperature excess" (difference between mean monthly water temperature and mean monthly equilibrium water temperature)

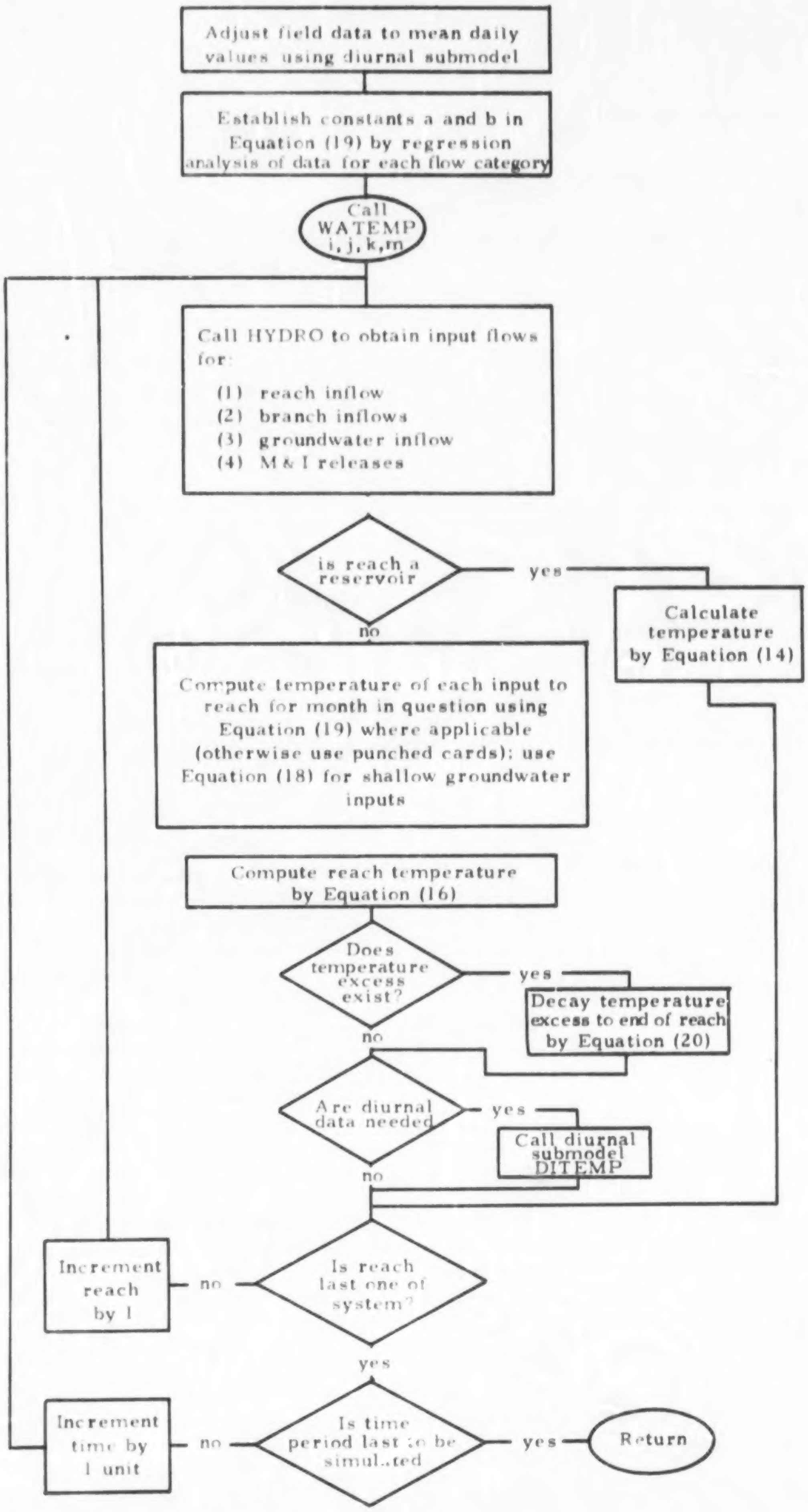

Adjust field data to mean daily values using diurnal submodel
Establish constants a and b in Equation (19) by regression analysis of data for each flow category
Call WATEMP i, j, k, m
Call HYDRO to obtain input flows for:
(1) reach inflow
(2) branch inflows
(3) groundwater inflow
(4) M & I releases
is reach a reservoir
yes
Calculate temperature by Equation (14)
no
Compute temperature of each input to reach for month in question using Equation (19) where applicable (otherwise use punched cards); use Equation (18) for shallow groundwater inputs
Compute reach temperature by Equation (16)
Does temperature excess exist?
yes
Decay temperature excess to end of reach by Equation (20)
no
Are diurnal data needed
yes
Call diurnal submodel DITEMP
no
Increment reach by 1
no
Is reach last one of system?
yes
Increment time by 1 unit
no
Is time period last to be simulated
yes
Return

Figure 14. Simulation algorithm for monthly water temperature.

exists at beginning of reach, apply Equation 20 to decay the excess temperature to the end of the reach.

7. Call diurnal submodel if desired.

8. Go to next reach and return to step 1.

9. If last reach is simulated, increment time by one month and return to step 1.

Steps 1, 7, 8, and 9 are done by WAQUAL; step 2 is done by the investigator in data preparation; steps 3, 4, 5, and 6 are done by WATEMP.

Diurnal water temperature simulation

Two continuous modeling stations were established at S-12.5 and S-20.5, respectively, to ascertain diurnal fluctuations and any stochastic effects for temperature, dissolved oxygen, pH, and conductivity. Analysis of thermographs from the continuous monitoring station at S-12.5 (which has about 18 months record) disclosed significant amplitudes in the 24 hour cycles in stream temperature. Since the diurnal temperature effect may well overshadow an annual variation or effects due to point discharges, any comprehensive model should include the diurnal effect for temperature. Thus a simulation procedure for assessing the temperature variation for the 24 hour cycle has been developed.

Researchers reporting diurnal variations in surface water temperature include Macan (1954), who has observed daily patterns of variation in water temperature of small streams in Britain. Duttweiler (1963) used diurnal variations in water temperature of a small stream in Maryland to estimate values of the heat exchange constant for that stream. Thomann (1967), on the other hand, found no significant 24 hour cycles in data from the Potomac estuary. This literature contains little information on the characterization of diurnal water temperature variations.

Establishing diurnal temperature equations

Thermographs were obtained at station S-12.5 in continuous blocks of from three to seven days in length. Twenty of these blocks of temperature data were recorded intermittently over an 18-month period. The diurnal data for each of these data blocks were then fitted to Equation 24, a two term Fourier series.

$$T_i = \overline{T} + \sum_{j=1}^{2} C_j \cdot \text{Sin}\left(\frac{2\pi j}{24} \cdot i + A_j\right) + \varepsilon_i \quad \ldots\ldots\ldots\ldots (24)$$

In Equation 24

T_i = observed stream temperature at the "i th" hour (°C)

$\overline{T}$ = mean daily stream temperature (°C)

i = hour of the day (measured continuously through the day, beginning with 0100 at 1:00 a.m. and ending with 2400 at midnight)

ε_i = deviation of the observed temperature for the "i th" hour from the model prediction for that hour

C_j and A_j = coefficient and phase shift for the "j th" term of the Fourier series, as determined by least squares analysis

Figure 15 shows hourly stream temperatures from a typical seven day continuous thermograph, with the best-fit Fourier series curve superimposed. During this particular period, the range of maximum stream temperatures was relatively high, as illustrated by the broad band of observation points about the curve. In spite of these relatively large deviations, Table 10 shows the coefficient of determination for this set of data to be 74 percent, meaning that Equation 24 explains 74 percent of the total variation in stream temperature during this period.

Dividing Equation 24 through by the mean daily temperature yields a predictive equation for the ratio of hourly to mean daily stream temperature

$$DTI_i = 1.0 + \sum_{j=1}^{2} C_j \cdot \text{Sin}\left(\frac{2\pi j}{24} \cdot i + A_j\right) + \varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots (25)$$

where now C_j and ε_i have been coded by division by $\overline{T}$, and $DTI_i = T_i/\overline{T}$. With patterns of diurnal temperature variation given in terms of this diurnal temperature index (DTI), the stream temperature at any hour of the day may be estimated by multiplying the mean daily temperature by the DTI for the hour in question.

Table 10 lists constants, C_1 and C_2, and phase angles, A_1 and A_2, for each of the two Fourier series terms and coefficient of determination, and average stream temperature over the period and corresponding average mean daily atmospheric temperature. It is interesting to note the apparent annual cyclic tendency in each of the Fourier series model parameters. This tendency is more obvious in Figure 16, where each model parameter is plotted as a function of time of year. These cyclic patterns probably result from seasonal variations in the number of daylight hours per day and intensity of solar radiation.

The Fourier series has again been employed in the characterization of the annual cyclic variations for each of the Equation 25 coefficients. Mean daily atmospheric temperature has also been incorporated to yield another Fourier series having the form

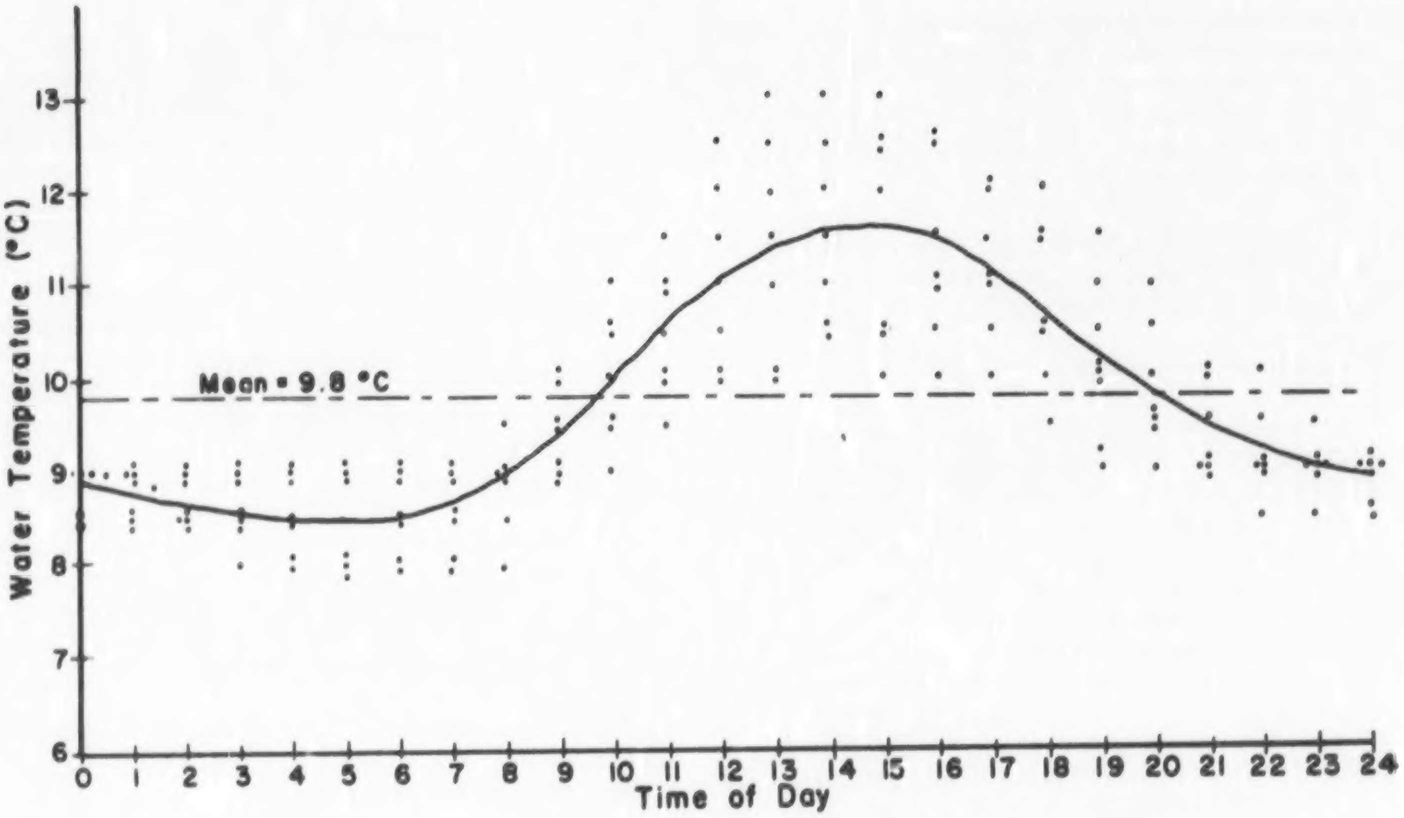


Figure 15. Water temperature variations for the period 22-29 April 1968 with Fourier series model.

Table 10. Diurnal temperature index (DTI) model parameters.

$$\left[DTI_i = 1.0 + \sum_{j=1}^{2} C_j \cdot \mathrm{Sin}\left(\frac{2\pi j}{24} \cdot i + A_j\right)\right]$$

Date	No. of days	C_1	A_1	C_2	A_2	R^2	T_w	$\overline{T}_a$	Notes
1127-120167	4	.169	3.654	.0760	.350	.45	6.4	26.8	
222-22968	6	.449	3.938	.2230	.294	.83	3.3	35.2	
229-30668	6	.514	3.908	.2234	.373	.91	4.3	39.2	
318-32568	7	.319	3.681	.0974	.267	.82	7.6	36.8	
325-32868	3	.328	3.669	.0761	-.054	.83	7.5	42.8	
404-40668	2	.093	3.910	.0351	.575	.68	7.0	40.5	Rain
417-42268	5	.101	4.047	.0185	1.047	.85	9.2	35.2	
422-42968	7	.150	3.946	.0179	1.140	.74	9.8	42.8	
517-52468	7	.094	3.624	.0182	-.428	.65	13.3	52.6	
524-53168	7	.119	3.556	.0202	-.316	.55	14.0	55.7	
531-60468	4	.142	3.164	.0247	-1.212	.76	15.4	59.3	
606-61268	6	.107	3.413	.0254	-.133	.41	7.1	56.8	Rain
624-62768	3	.182	3.222	.0292	-.520	.97	14.8	63.7	
701-70868	7	.244	3.292	.0479	-.501	.93	14.2	68.2	
1004-100668	2	.206	3.249	.0443	-.491	.97	12.4	53.7	
1009-101368	4	.145	3.277	.0429	-.631	.56	11.7	54.5	
1023-102968	7	.222	3.339	.0836	-.552	.85	8.6	47.7	
1030-110568	7	.136	3.458	.0348	-.343	.62	7.5	42.4	
1106-111068	5	.183	3.682	.0667	-.016	.71	6.6	38.5	
1203-121068	7	.516	3.533	.1838	-.093	.75	2.4	29.3	

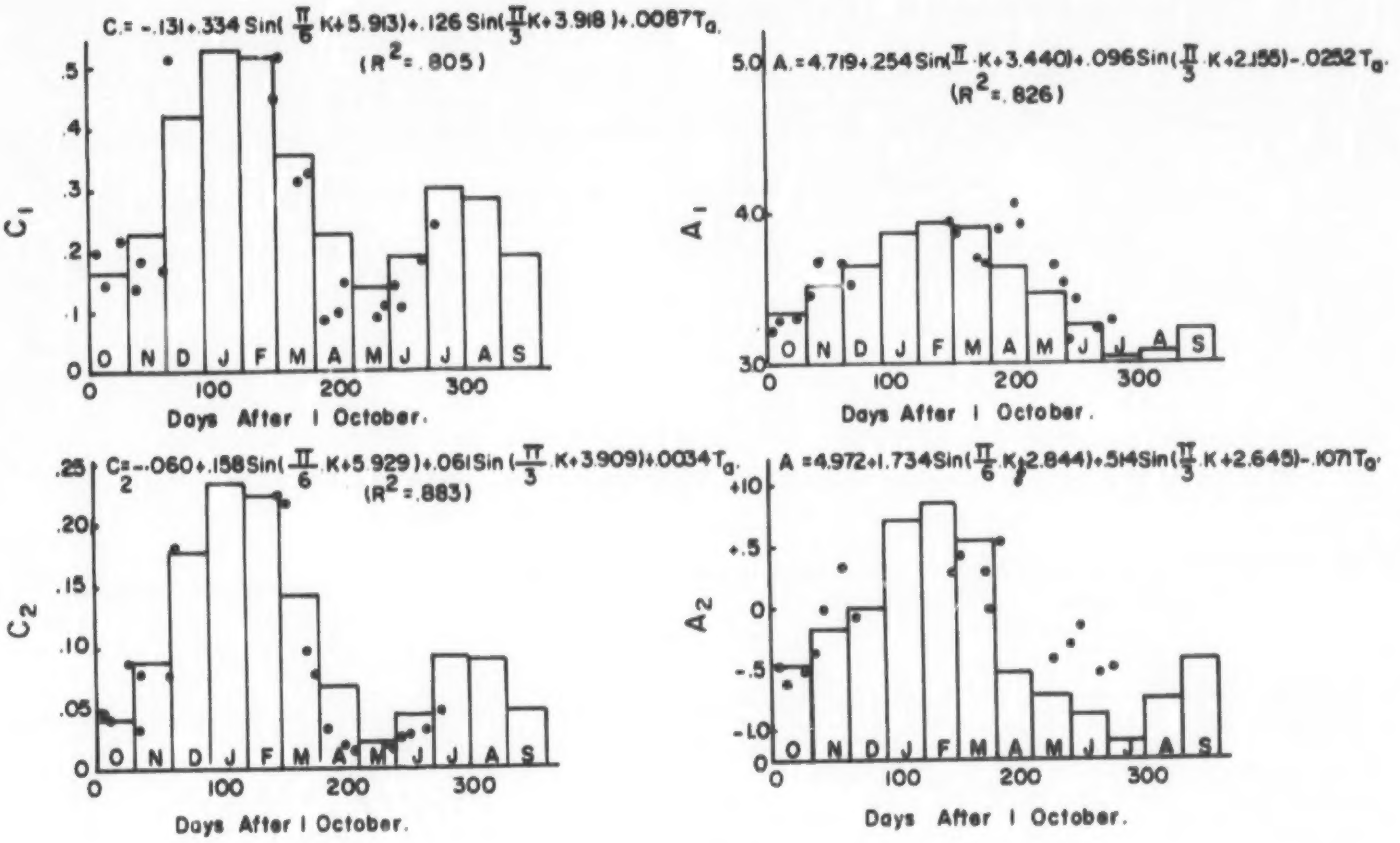


Figure 16. Annual variations in diurnal temperature index model parameters.

$$Y = c_o + \sum_{j=1}^{2} c_j \cdot \mathrm{Sin}\left(\frac{2\pi j}{365} \cdot x + a_j\right)$$

$$+ r \cdot \overline{T}_a + \varepsilon \quad \ldots\ldots\ldots\ldots\ldots (26)$$

in which

Y = diurnal index equation coefficient, A_1, A_2, C_1 or C_2 for a given month

x = days since 1 October

$\overline{T}_a$ = mean daily atmospheric temperature for a given month (°F)

ε = deviation of predicted model parameter value for a given date from the value calculated from diurnal variations observed on that date

c_o, c_j, a_j and r = constants and phase shift as determined by least squares analysis for the respective Y

Monthly values of the DTI model parameters (A_1, A_2, C_1 and C_2), as estimated by Equation 26 are shown in Figure 16 as bars and are listed also in Table 12. The dearth of data points in Figure 16 for the months of January, August, and September was caused by malfunctions in the continuous monitoring instrumentation for those months.

Table 11 lists the coefficients c_0, a_1, a_2, c_1 and c_2 belonging to Equation 26. These coefficients were obtained by regression analysis of each coefficient represented by Y in Equation 26.

Figure 17 shows graphically Equation 25 for each month of the year. The seasonal pattern exhibited in the monthly diurnal index sine curves is allowed by the monthly assessment of Equation 25 coefficients, which is done by Equation 26. To convert from index display to real temperature it is necessary only to multiply each ordinate by $\overline{T}$, the mean monthly stream temperature.

Diurnal stream temperature simulation

The diurnal distribution of temperature and flow in all hydrologic input streams must be defined before hourly variations in stream temperature may be approximated. All natural surface inflows to the system are assumed to exhibit the same hourly distribution of temperature indexes. Figure 18 shows substantial similarity in patterns of variation at stations S-12.5 and S-20.5

Table 11. Representation of annual changes in diurnal water temperature index model parameters for Equation 26.

Parameter	c_o (constant)	c_1 (constant)	a_1 (radians)	c_2 (constant)	a_2 (radians)	r (constant)	R^2 (%)
$Y = C_1$	.131	.334	5.913	.126	3.918	.009	80.
$Y = A_1$	4.719	.254	3.440	.096	2.155	-.025	83.
$Y = C_2$	-.060	.158	5.929	.061	3.908	.003	88.
$Y = A_2$	4.972	1.734	2.844	.514	2.645	-.107	79.

Table 12. Estimated monthly values of diurnal temperature index model parameters for Equation 25, calculated by Equation 26 using Table 11 coefficients.

Month	C_1 (constant)	A_1 (radians)	C_2 (constant)	A_2 (radians)
October	.160	3.333	.039	-.476
November	.230	3.531	.083	-.161
December	.420	3.647	.179	.000
January	.530	3.860	.235	.703
February	.513	3.934	.223	.839
March	.357	3.896	.140	.547
April	.227	3.618	.067	-.536
May	.139	3.463	.020	-.731
June	.191	3.257	.042	-.875
July	.300	3.037	.088	-1.156
August	.281	3.077	.082	-.747
September	.191	3.216	.046	-.419

on October 11-12, 1968. While the agreement is not exact, the approximation is satisfactory for the purposes of this study. Hourly temperatures, τ, of natural surface inflows are estimated by multiplying the mean monthly temperature, $\bar{\tau}$, for these inflows, taken from the monthly simulation, by the diurnal temperature index. Table 13 summarizes the methods employed in simulating hourly time variations in the temperature of the hydrologic inputs to the reach. Diurnal fluctuations in expected "equilibrium" stream temperature are also assumed to be characterized by this same temperature index distribution; mean monthly water temperature, $\overline{T}$, from Equation 19 is the basis for applying the DTI for the input in question.

It is shown in Table 13 that groundwater flows are assumed free from diurnal influences. Also shown in Table 13 is the card input characterization of municipal-industrial discharges.

Table 13. Diurnal temperature input models.

Input	Model
River inflow	previous simulation of upstream reach
Branch inflow	previous simulation of upstream reach
Surface inflow	$\tau_s = \bar{\tau}_s \cdot DTI$
Irrigation return flow	$\tau_i = \bar{\tau}_i \cdot DTI$
Groundwater inflow	$\tau_g = \bar{\tau}_g$
M & I releases	card input

Reservoir releases may or may not exhibit diurnal variations, depending upon the depth from which they are drawn. Waters spilled from the upper several feet of reservoir storage would be expected to show diurnal patterns of variation in response to the influence of daily cycles in

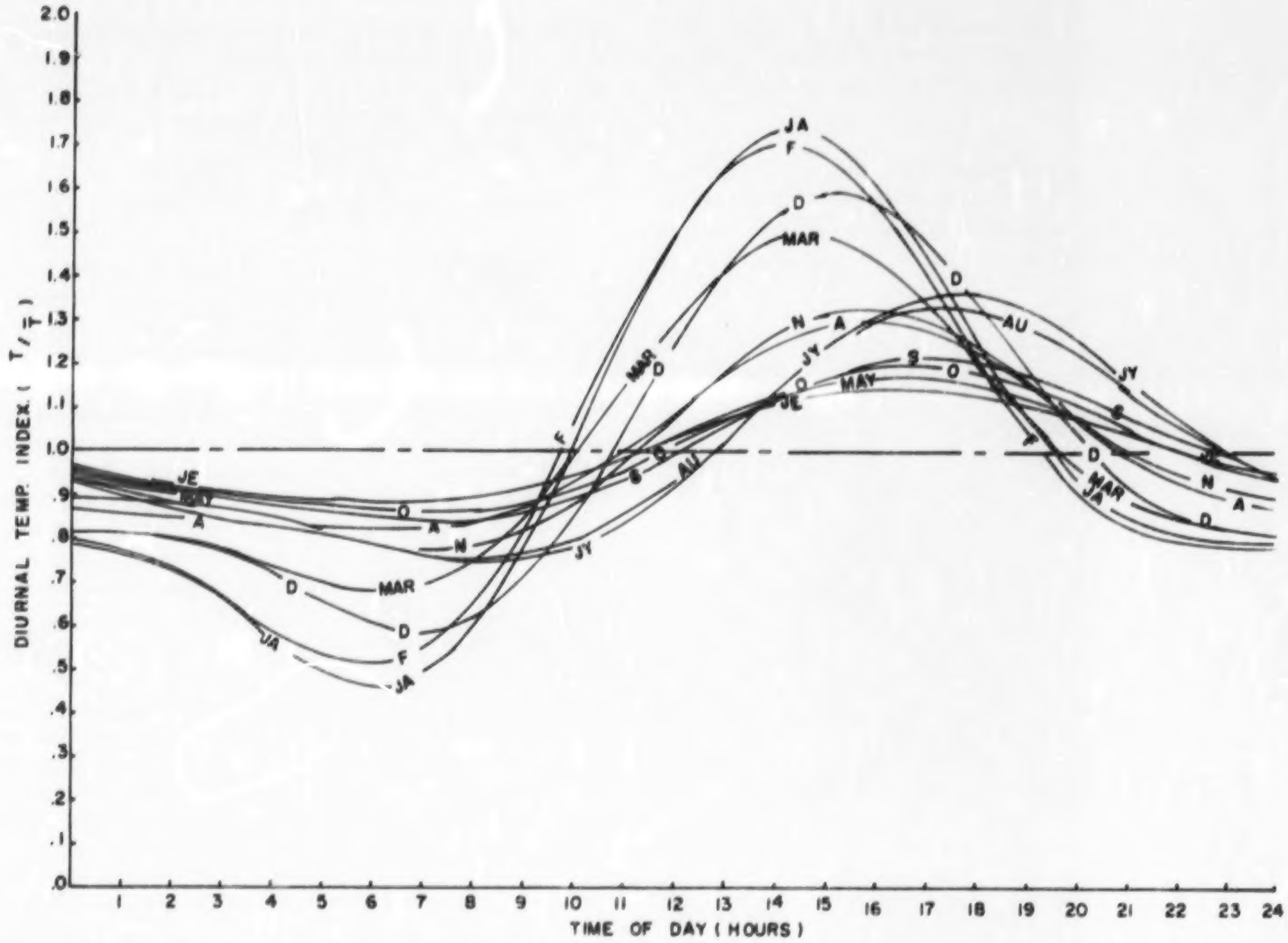


Figure 17. Diurnal temperature index models for each month of the year.

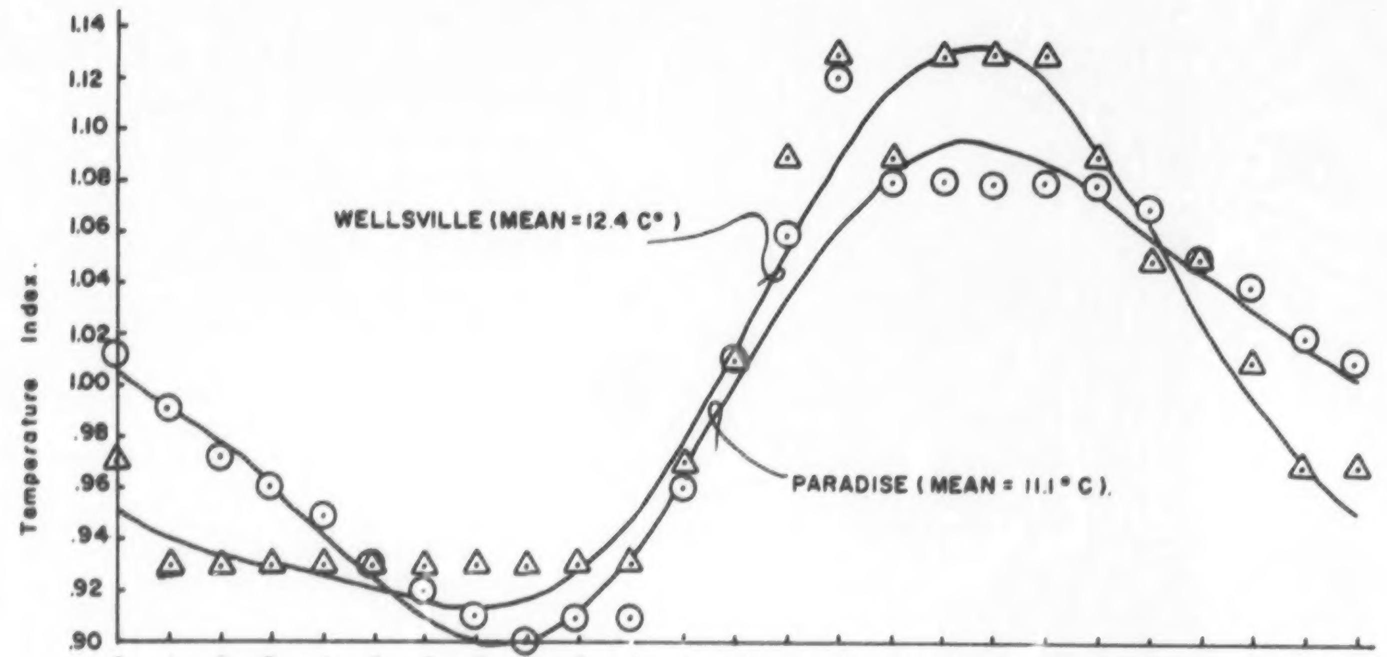


Figure 18. Comparison of stream temperature index patterns on the Little Bear River at Wellsville and Paradise on 11-12 Oct. 1968.

atmospheric conditions. Waters originating in the hypolimnion, on the other hand, are shielded from the effect of atmospheric conditions so that diurnal fluctuations are not observed.

Each of the inputs described above are "mixed" on an hour by hour basis in accordance with Equation 16 (again used with temperatures); this gives the hourly stream temperature distribution at the upstream end of the reach.

A graphical example of the combination of a natural stream inflow and a municipal waste discharge is presented in parts (a), (b) and (c) of Figure 19. Diurnal temperature distributions for the two components of flow (QS and QEF) are depicted in (a) and (b) respectively. The distribution of rate of waste discharge is also shown in part (b). Ordinates to the hourly temperature distribution for the combined flow, shown in part (c), are calculated for each hour by the mixing formula (Equation 16), with hourly temperatures for each of the components being substituted for conductivity.

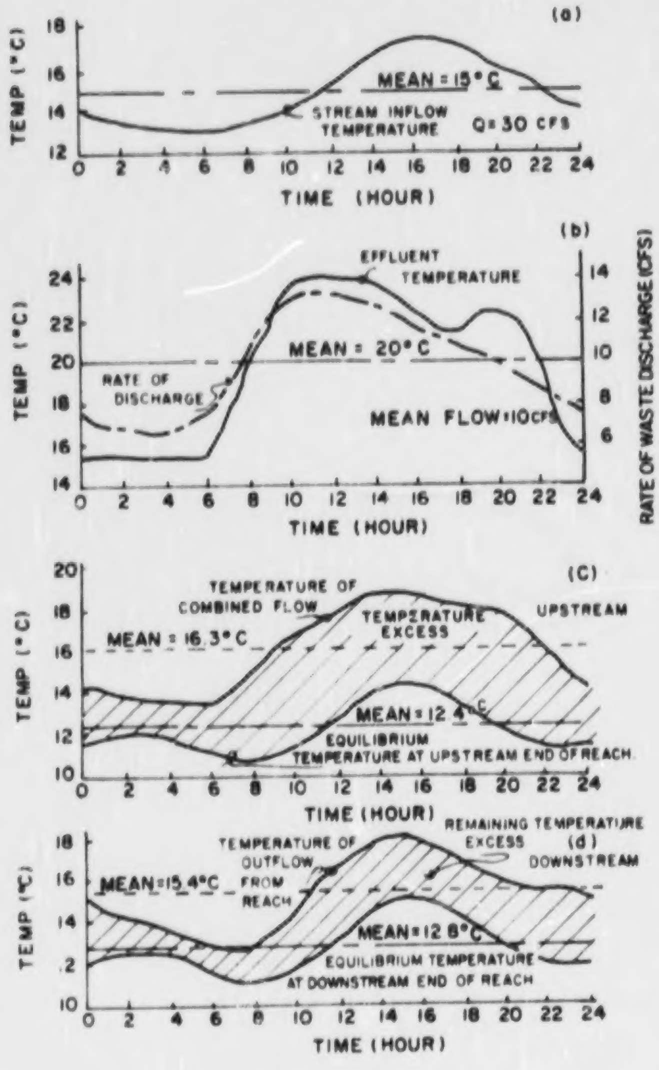


Figure 19. Graphical representation of diurnal temperature computations.

In-transit and diurnal changes

Diurnal changes in water temperature within a river reach are determined in the same manner as in the monthly temperature simulation, except that any "temperature excess" due to heat inputs into the stream must be routed through the reach except that in routing the temperature excess through the reach time of travel must be considered. The simulation is performed hour-by-hour over the full 24 hour cycle. The procedure is illustrated with conditions and results shown in Figure 19. Figure 19a is the diurnal temperature pattern of the "natural" stream. Figure 19b is the diurnal patterns of temperature and flow for a hypothetical municipal input. Figure 19c shows the temperature variation of the combined flow in the top boundary, calculated by Equation 16 for each hour. The bottom boundary is the "equilibrium temperature," which was obtained by multiplying the hourly diurnal temperature index, DTI$_i$, by the mean monthly temperature obtained from Equation 19. The difference between these boundaries is the "temperature excess," at the upstream end of the reach. Figure 19d is the temperature pattern at the downstream end of the reach, which is assumed two hours in travel time from the upstream end. This result is obtained by decaying the excess in Figure 19c by Equation 27. Repeating this procedure for each hour of the day gives the hourly distribution of temperatures at the downstream end of the reach.

$$T_2(t_2) = \left\{ \frac{\sum_{j=1}^{nc} [q_j(t_1) \cdot \tau_j(t_1)]}{Q} - E_1(t_1) \right\} \cdot e^{-\phi} + E_2(t_2) \quad .(27)$$

in which

$T_i(t)$ = time distribution of stream temperature at point i, evaluated at time t

$E_i(t)$ = time distribution of "equilibrium" temperature at point i, and time t; $[E_i(t) = E_i \cdot DTI_i(t)]$

$q_j(t)$ = rate of flow of input j at time t

$\tau_j(t)$ = temperature of input j at time t

$$Q = \sum_{j=1}^{n} q_j(t)$$

nc = number of hydrologic inputs to the reach

$\phi = \frac{.0235 \cdot k \cdot W}{Q} \cdot D$

t_1 = time of inflow at upstream end of reach

t_2 = time of outflow at downstream end of reach

In this formulation the subscript 1 designates the upstream end of the reach, while 2 indicates the downstream end. Allowing t_1 to vary in increments of one hour through 24 results in the definition of the diurnal temperature distribution at the downstream end of the reach at one hour intervals. The difference between t_1 and t_2 is the travel time through the reach.

Algorithm for simulation

Figure 20 conceptually outlines the simulation algorithm for monthly stream temperature, and is summarized below.

1. Obtain monthly flow values for all inputs from hydrologic model.
2. Feed in mean daily atmospheric temperature for each month.
3. Obtain mean monthly temperature for month in question using monthly model WATEMP.
4. Obtain Fourier coefficients a_1, a_2, c_1, c_2 for Equation 26 by regression analysis.
5. Compute monthly values of Fourier coefficients C_1, C_2, A_1, A_2, for Equation 25.
6. Compute diurnal temperature index, DTI_i, for each hour of day (for the given month) by Equation 25.
7. Compute hourly temperatures by multiplying DTI_i by mean daily water temperature for month in question.
8. For each hour compute temperature of all inputs and obtain mixed stream temperature as per Equation 16.
9. For each hour decay any temperature excess at beginning of reach to the downstream end of reach—as per Equation 27; using proper values of equilibrium temperature for the hour in question.
10. Return to step 1 and repeat procedure for following reach.
11. If entire stream is simulated go to step 1 and repeat, incrementing time by one month.

Steps 4 and 5 are the data preparation steps; steps 1, 2, 3, 10, 11 are done by WAQUAL; steps 6, 7, 8, and 9 are done by DITEMP.

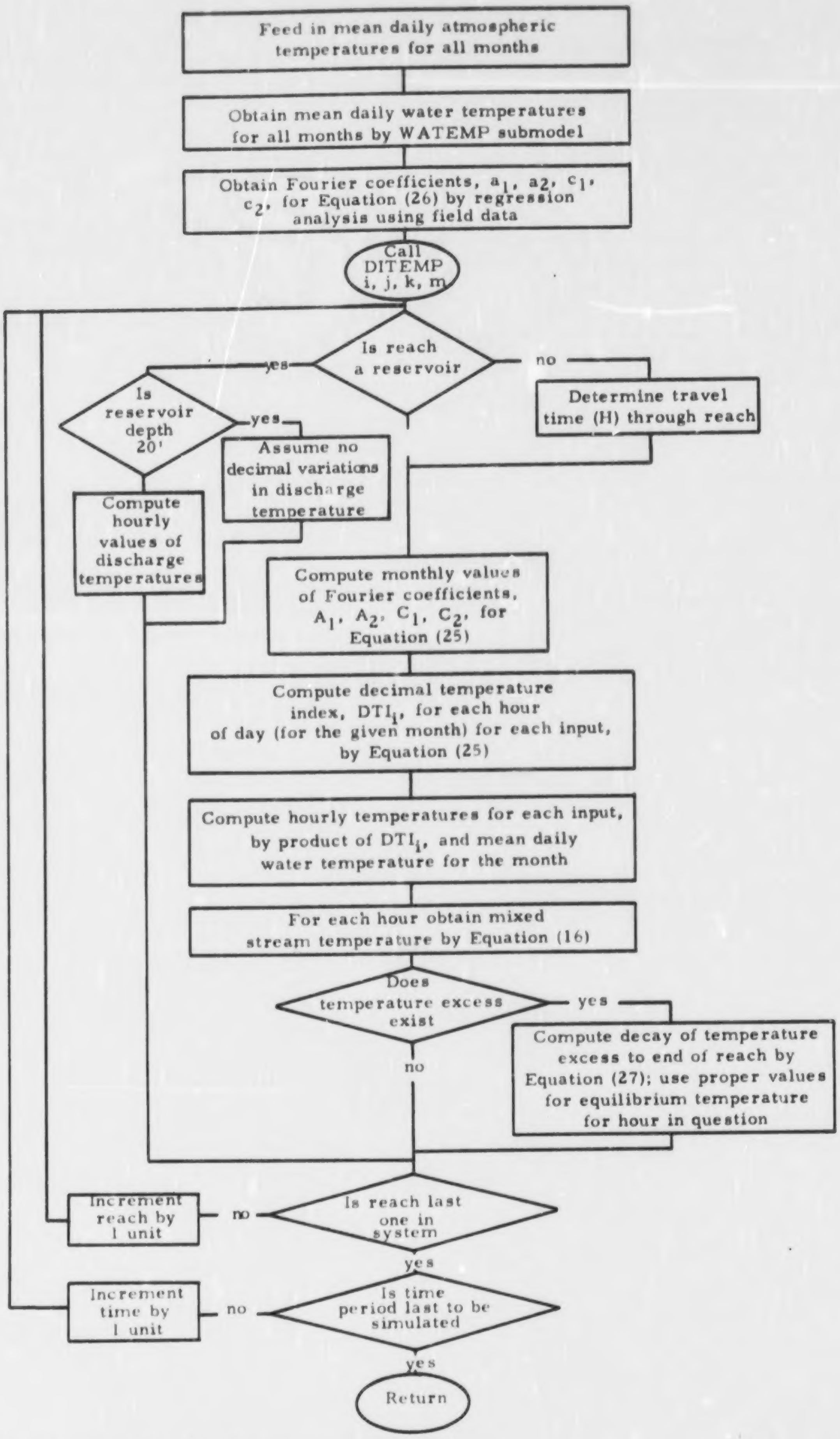

Feed in mean daily atmospheric temperatures for all months
Obtain mean daily water temperatures for all months by WATEMP submodel
Obtain Fourier coefficients, a1, a2, c1, c2, for Equation (26) by regression analysis using field data
Call DITEMP i, j, k, m
Is reach a reservoir
yes
no
Determine travel time (H) through reach
Is reservoir depth 20'
yes
Assume no decimal variations in discharge temperature
Compute hourly values of discharge temperatures
Compute monthly values of Fourier coefficients, A1, A2, C1, C2, for Equation (25)
Compute decimal temperature index, DTI1, for each hour of day (for the given month) for each input, by Equation (25)
Compute hourly temperatures for each input, by product of DTI1, and mean daily water temperature for the month
For each hour obtain mixed stream temperature by Equation (16)
Does temperature excess exist
yes
Compute decay of temperature excess to end of reach by Equation (27); use proper values for equilibrium temperature for hour in question
no
Increment reach by 1 unit
no
Is reach last one in system
yes
Increment time by 1 unit
no
Is time period last to be simulated
yes
Return

Figure 20. Simulation algorithm for diurnal water temperature.

CHAPTER VI

DISSOLVED OXYGEN SIMULATION

Dissolved oxygen concentration (D.O.) is probably the one characteristic of the water resource pool most frequently cited as an indication of its quality. Whether at saturation, excess, or deficient, the level of D.O. tells considerably about the biotic state of a water body. Low D.O. levels are associated with esthetically undesirable conditions and carry an implication of possible health hazard. Maintenance of a desirable freshwater fishery is perhaps the most important reason for concern about D.O. conditions. In addition, nuisance conditions may prevail should the D.O. levels reach an extreme in either direction of saturation. Thus it is important to understand the temporal D.O. behavior of a stream and also its spatial and temporal response to any imposed waste conditions.

The submodels developed herein consider the temporal changes in D.O. at two levels of time resolution—the month and the hour, for simulation of annual and diurnal cycles, respectively. In addition, the effects of waste inputs are assessed with respect to distance. Again the approach is quite pragmatic; this consists of finding a suitable mathematical relationship which can simulate the D.O. behavior of the stream, and then determining the proper coefficient values by regression analysis of a set of arguments consisting of field data.

In-transit changes

The term "in-transit change" is used with reference to the effects of the processes associated with movement within the stream. In its simplest form the "in-transit change" is simulated by the familiar Streeter-Phelps equation consisting of dissipation by decomposition and respiration reactions and mass transfer of oxygen by turbulent diffusion through the surface. Both are first order kinetic reactions. As originally proposed by Streeter and Phelps (1925), the equation for stream deoxygenation is:

$$\frac{dL_s}{dt} = -K_1 \cdot L_s = -\frac{dD}{dt} \quad . . . (28)$$

in which L_s is the ultimate biochemical oxygen demand (BOD), t is time and K_1 is the first-order rate constant.

The process of stream reoxygenation is first order with respect to oxygen deficit:

$$\frac{dDO}{dt} = K_2 \cdot (C_s - DO) = K_2 \cdot D = \frac{-dD}{dt} . \quad . (29)$$

Here D.O. is the concentration of dissolved oxygen, C_s is the oxygen saturation concentration, $D = (C_s - C)$ is the D.O. deficit and K_2 is the unimolecular reaeration rate constant.

After combining the deoxygenation and reoxygenation process and integrating, the equation takes the form:

$$D_b = \frac{K_1 \cdot L_{sa}}{K_2 - K_1} \cdot e^{-K_1 \cdot t} - e^{-K_2 \cdot t} + D_a \cdot e^{-K_2 \cdot t} \quad . . . . (30)$$

in which the subscripts "a" and "b" designate initial and subsequent concentrations, respectively, after an elapsed time, t.

Although this original formulation is a gross simplification of the complex interrelated processes involved, it has been of great importance in the development of the theory, as it stands today. In fact, most of the models currently found in the literature are based upon the unimolecular rate theory with modifications added, to account for the influence of other processes, such as scour, sedimentation, oxygen demand by benthal deposits, photosynthesis, etc.

The Streeter-Phelps oxygen sag equation (Equation 30) is the classical representation of in-transit dissolved oxygen level changes for a polluted stream. This simple formulation considers only the surface reaeration and bacterial deoxygenation processes. Many other processes may enter into the oxygen balance of a stream. Dobbins (1964) lists several of these processes as:

1. Sedimentation or adsorption of BOD.
2. Resuspension of settled organic deposits by scour action on benthal deposits or upward diffusion of partly decomposed organic matter from the stream benthos.
3. BOD increase by local runoff.
4. Oxygen demand by the aerobic zone of the benthal layer.
5. Oxygen removal by the stripping action of gases rising from the anaerobic decomposition of the benthal layer.
6. Photosynthetic oxygen production by plankton and periphyton.
7. Oxygen removal by respiration of plankton and periphyton.
8. Longitudinal dispersion.

Several researchers have proposed modifications to the Streeter-Phelps equation to integrate into it one or more of the above processes (Thomas, 1948; Li, 1962; Dobbins, 1964; Camp, 1965; and O'Connor, 1967). The work of Hansen and Frankel (1965) brings together, in a rather concise form and in a consistent set of nomenclature, most of the basic concepts presented by their predecessors. In addition, they propose a cyclic expression to represent diurnal variations in photosynthetic production and respiratory uptake of oxygen by photosynthetic organisms. Their equation in integrated form is:

$$D_b = D_a \cdot e^{-K_2 \cdot t} + \frac{(K_1 + K_r) \cdot (1 + K_3/K)}{(K_2 - K)} \cdot \left(L_{s_a} - \frac{p}{K}\right) \cdot \left(e^{-K_1 \cdot t} - e^{-K_2 \cdot t}\right) + \frac{K_4}{K_2 - K_4} \cdot \left(\frac{L_{d_o}}{H} + \frac{p}{K_4}\right) \cdot \left(e^{-K_4 \cdot t} - e^{-K_2 \cdot t}\right) - \alpha\,(K_2 \cos \beta + \omega \sin \beta)\, e^{-K_2 \cdot t} + \alpha\,[K_2 \cos(\omega t + \beta) + \omega \sin(\omega t + \beta)] \quad \ldots\ldots\ldots\ldots (31)$$

in which

D_a = oxygen deficit of a volume of water as it enters the reach (mg/l)

D_b = oxygen deficit of the same volume as it leaves the reach (mg/l)

L_{s_a} = ultimate first stage BOD in solution and suspension as the flow enters the reach (mg/l)

L_{d_o} = initial areal BOD of the benthic zone (g/sq·meter)

K_1 = laboratory rate of deoxygenation (base e, day^{-1})

K_2 = reoxygenation rate constant (base e, day^{-1})

K_3 = rate constant for BOD removal by sedimentation and/or adsorption (base e, day^{-1})

K_4 = rate constant for the anaerobic fermentation of benthal deposits (base e, day^{-1})

K_r = the difference between the actual instream deoxygenation constant and laboratory rate constant (base e, day^{-1})

K = $K_1 + K_r + K_3$

p = rate of addition of BOD to the stream water from the benthal layer (mg/l·day)

t = travel time through the reach (days)

H = stream depth (meters)

α = $a/(\omega^2 + K_2^2)$ (mg/l·day)

a = maximum rate of production (consumption) of oxygen by photosynthesis (respiration) (mg/l·day)

ω = $2\pi/24$

β = $2\pi/24 \cdot lt$

lt = lag time at which respiration of aquatic organisms in the stream below the tributary is a maximum

Assuming no net increase in D.O. due to the activity of photosynthetic organisms over the typical 24 hour cycle, the monthly average of changes in D.O. within a reach may be represented by the first three terms of Equation 31, which is restated as Equation 32:

$$D_b = D_a \cdot e^{-K_2 \cdot t} + \frac{(K_1 + K_r) \cdot (1 + K_3/K)}{(K_2 - K)} \cdot \left(L_{s_a} - \frac{p}{K}\right) \cdot \left(e^{-K_1 \cdot t} - e^{-K_2 \cdot t}\right) + \frac{K_4}{K_2 - K_4} \cdot \left(\frac{L_{d_o}}{H} + \frac{p}{K_4}\right) \cdot \left(e^{-K_4 \cdot t} - e^{-K_2 \cdot t}\right) \quad \ldots . (32)$$

Equation 32 was programmed as a part of the dissolved oxygen submodel used in this work.

The assumption of no net effect due to photosynthetic organisms may require further justification. During daylight hours, photosynthetic oxygen production exceeds the respiratory requirements of the aquatic community as indicated in Figure 21. These same photosynthetic organisms become users of oxygen during periods of darkness. The net effect of the photosynthetic organisms over a 24 hour cycle is the difference between the amount of oxygen produced during the day (the cross hatched area under the curve) and the amount consumed at night (the cross hatched and stippled area above the curve).

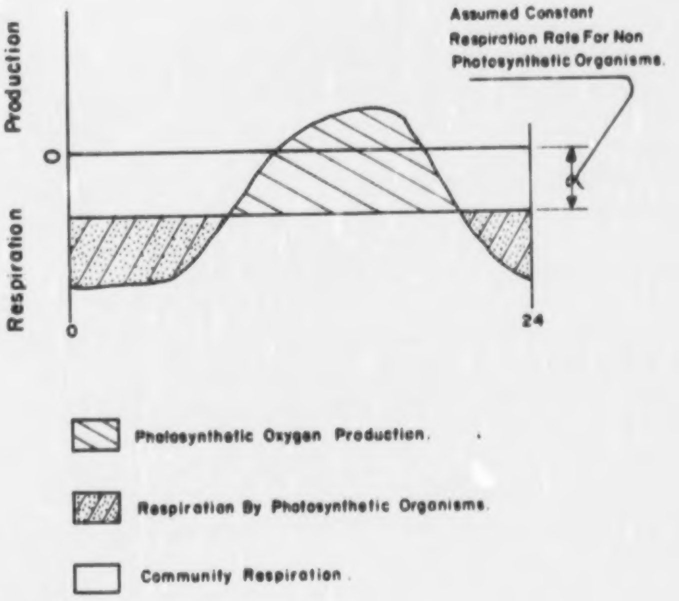


Figure 21. Dissolved oxygen variations at station S-12.8 for 1966-67 with best fit Fourier series curve.

Studies have been conducted to assess the productivity of certain streams. Hoskin (1960) reports photosynthetic oxygen production rates of 87.7 pounds per acre of stream surface per day and community respiration rates of 192 pounds per acre per day in streams of North Carolina. Edwards and Owens (1962) found oxygen production in an English chalk stream to vary from 28.6 to 158 pounds per acre per day while community respiration ranged between 59.9 and 139 pounds per acre per day. It should be emphasized that the above respiration figures relate to the combined respiration of photosynthetic and nonphotosynthetic organisms, represented in Figure 21 as the area bounded by the assumed respiration rate for nonphotosynthetic organisms and the zero abscissa, plus the stippled area.

O'Connell and Thomas (1965), in their study of the Truckee River below Reno, Nevada, found oxygen production to average about 72.5 pounds per acre per day, while respiration of photosynthetic organisms proceeded at the rate of 65.4 pounds per acre per day. While the figures of O'Connell and Thomas indicate a possible net production of oxygen by photosynthesis, some of the oxygen produced undoubtedly escapes to the atmosphere.

Suspended BOD

Changes in dissolved and suspended BOD within a reach have been represented as

$$L_{s_b} = \left(L_{s_a} - \frac{p}{k}\right) \cdot e^{-K \cdot t} + \frac{p}{K} \quad . \ . (33)$$

by Hansen and Frankel (1965) where L_{s_b} is the BOD of the flow as it leaves the reach being studied and other variables are as defined above.

For the case where scour is taking place ($K_3 = 0$), but not sedimentation ($p \neq 0$), the change in BOD of the benthal deposit within the reach was represented by Hansen and Frankel as

$$L_{d_t} = L_{d_o} \cdot e^{-K_4 \cdot t}$$

$$- \left(1 - e^{-K_4 \cdot t}\right) \cdot \frac{H_m \cdot p}{K} \ldots . (p \neq 0,$$

$$K_3 = 0) \quad . \ . \ . \ . \ . \ . \ . \ . (34)$$

in which L_{d_o} is the initial areal BOD of the benthic deposit and L_d in the areal BOD of the deposit after time "t." This equation may be applied directly to the simulation of month to month changes in the benthal BOD of a stream simply by letting t = 30 days.

In the case of sedimentation ($K_3 \neq 0$ and $p = 0$), Hansen and Frankel assume that the rate of deposition is exactly balanced by the rate of anaerobic fermentation so that there is no net buildup of organic material in the benthal region. This assumption seems unduly restrictive for modeling over an extended period. To fill the need for a model to simulate possible increases in benthal BOD during certain periods of the year, the following has been developed.

It is obvious that BOD removed from suspension by sedimentation and/or adsorption must appear as increased benthal BOD. Assuming that this removal rate is adequately represented by a first order kinetics model of the form

$$\frac{dL_s}{dt} = K_3 \cdot L_s$$

integration yields

$$L_{s_b} = L_{s_a} \cdot e^{-K_3 \cdot t} \quad \ldots\ldots (35)$$

The change in L_s, due to sedimentation and adsorption, as the flow passes through the reach a-b is

$$\Delta L_s = L_{s_a} - L_{s_b} = L_{s_a} \cdot \left(1 - e^{-K_3 \cdot t}\right) \quad \ldots\ldots\ldots\ldots (36)$$

where L_s is measured in mg/l or gm/meter^3. On an areal basis this means that the amount of BOD deposited is (assuming uniform deposition over the benthal region of the reach):

$$\Delta L_d = Hm \cdot \Delta L_s = Hm \cdot L_{s_a} \cdot \left(1 - e^{-K_3 \cdot t}\right) \quad \ldots\ldots\ldots\ldots (37)$$

in gm/meter^2.

Using monthly averages, the amount deposited in this reach per month is

$$\Delta L_d = Hm \cdot L_{s_a} \cdot \left(1 - e^{-30 \cdot K_3}\right) \quad \ldots (38)$$

in which H is the monthly average of the mean stream depth (in meters), and L_{s_a} is the monthly average of suspended and dissolved BOD in the flow entering the reach.

Assuming areal BOD of the benthos at the beginning of the month to be L_{d_o} and that during the month one half of the amount of BOD deposited is subjected to anaerobic decomposition for a period of 30 days, the equivalent initial areal BOD (L_{d_o}) may be written

$$L_{d_{30}} = L_{d_o} + 1/2\ Hm \cdot L_{s_a} \cdot \left(1 - e^{-30K_3}\right) \quad \ldots\ldots\ldots (39)$$

Substituting into the integrated first order reaction equation for anaerobic fermentation for p = 0:

$$L_{d_t} = L_{d_o}\ e^{-K_4 \cdot t} \quad \ldots\ldots (40)$$

gives

$$L_{d_{30}} = \left[L_{d_o} + 1/2\ Hm \cdot L_{s_a} \cdot \left(1 - e^{-30K_3}\right)\right] \cdot e^{-30K_4} \quad \ldots\ldots\ldots\ldots\ldots (41)$$

This expression predicts L_d at the beginning of the following month when p = 0 and $K_3 \neq 0$. Equation 34 applies where $p \neq 0$ but $K_3 = 0$. If both K_3 and p are zero this means that only anaerobic fermentation is affecting the amount of organic material in the benthal deposit. Both Equations 34 and 41 reflect this situation.

Determination of rate constants

The in-transit dissolved oxygen equation of Hansen and Frankel contains many rate constants and other parameters. Estimation procedures for a few of these are found in the literature. Those for which estimation procedures are available include oxygen saturation concentration (C_s), stream reaeration rate constant (K_2), ultimate dissolved and suspended BOD (L_s) and laboratory deoxygenation rate constant (K_1). The relationships employed herein for the estimation of these parameters are discussed below.

Oxygen saturation. The ASCE Committee on Sanitary Engineering Research (1960) has established the relationship between oxygen saturation concentration, C_s, and water temperatures, T (in degrees Centigrade), for fresh water exposed to standard atmospheric at mean sea level as

$$C_s = 14.652 - .41022\ T + .0079910\ T^2 - .000077774\ T^3 \quad \ldots\ldots\ldots\ldots (42)$$

Saturation concentrations calculated from this expression differ slightly from those published in Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1965).

Saturation concentrations obtained from Equation 42 are for sea level (760 millimeters of mercury) and may be adjusted for other atmospheric pressures by multiplying by the following pressure correction factor (cf):

$$cf = \frac{P - pv}{760 - pv} \quad \ldots\ldots (43)$$

in which P is the observed atmospheric pressure in millimeters of mercury and pv is the vapor pressure of water at the prevailing water temperature. Figure E-2, Appendix E, is a nomograph showing such relationships.

Reoxygenation rate constant. The reoxygenation rate constant has been demonstrated to be closely related to the flow characteristics of the stream. Owens, Edwards, and Gibbs (1964) have integrated data collected by themselves and others, covering a wide range in flow conditions, in the derivation of the expression

$$k_2(20) = 9.41 \cdot V^{.67} \cdot H^{-1.85} \quad \ldots (44)$$

in which $k_2(20)$ is the reoxygenation rate constant (base 10) for a natural stream at 20°C, V is the mean velocity of flow (ft./sec.) and H is the mean flow depth (ft.). The relationship between the rate constant and water temperature has been characterized as

$$k_2(T) = k_2(20) \cdot 1.0241^{(T-20)} \quad \ldots (45)$$

by Elmore and West (1961). This expression was later used by Churchill et al. (1962) in their exhaustive study of the reaeration of natural streams. In Equation 45 T is water temperature (°C) and $k_2(T)$ is the rate constant at temperature T (base 10, day^{-1}). Because the reaeration rate constant is a characteristic of the channel reach and not of inflowing waters, it was not necessary to define this variable for each inflow.

Deoxygenation rate constant. The deoxygenation rate constant is affected by water temperature, as depicted by the expression

$$k_1(T) = k_1(20) \cdot \theta^{(T-20)} \quad \ldots (46)$$

where $k_1(20)$ is the rate constant for 20°C and $k_1(T)$ is that for the temperature under which the actual oxygen consuming reaction takes place. Fair, Geyer, and Okun (1968) report values of θ ranging from 1.15 at 5°C to 0.97 of 35°C. This variation has been approximated in this study as follows:

$$\left.\begin{aligned} \theta &= 1.065 - .0012 \cdot (T-5) \quad \text{for } T < 20^\circ C \\ \theta &= 1.047 \quad\quad\quad\quad\quad\quad\quad \text{for } T > 20^\circ C \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots (47)$$

The rate of oxygen demand is governed by the rate of aerobic decomposition of organic materials dissolved or suspended in the water, which is influenced by the density and type of microbial population, concentration and composition of the waste, water temperature, etc. Deoxygenation rate constants found in the literature vary widely. Hansen and Frankel (1965) used values of $K_1 + K_r$ (deoxygenation rate in the stream) of from 0.30 to 0.42 (day^{-1}). Fair, Geyer, and Okun (1968) and McGauhey (1968) cite a value of 0.23 as the "nominal" value for K_1 (base e) for waters receiving settled domestic waste water. Kothandaraman (1968) cites data from the Ohio River in which K_1 varies from 0.31 to 0.05 (day^{-1}). These are equivalent to base 10 constants (k_1) of 0.134 and 0.022 respectively.

Several procedures for estimating the ultimate BOD and the rate constant have been presented in the literature (Thomas, 1937; Moore, Thomas and Snow, 1950; and Sheehy, 1960). Attempts to apply these methods to the low level BOD's of this system were largely unsuccessful because the BOD's were below the range for which the techniques were established. In a short reach immediately below the trout farm discharge, BOD levels were found to be high enough to allow the application of these procedures.

Samples from several points on the river downstream from the trout farm exhibited laboratory rate constants, k_1 (base 10), ranging from 0.15 to 0.08 day^{-1}. Figure 22 shows the results of these tests. Similar values were obtained below the Wellsville sewer outfall, though here again low BOD levels rendered the computational procedure approximate at best. Values for the deoxygenation rate constant (base 10) in surface inflows were assumed to be 0.15 (day^{-1}) for this work.

Discrete BOD loads in the Little Bear River

To assess the effect of a municipal or industrial waste on the oxygen resource of a river system, the initial dissolved oxygen concentration, BOD level, and deoxygenation rate constant of the waste stream need to be defined. Data from the two concentrated waste sources on the Little Bear River show a small annual variation in oxygen concentration. Concentrations ranged from 6.8 to 11.5 mg/l at the Wellsville discharge and from 3.7 to 10.6 mg/l at the trout farm.

Though BOD levels in the two effluents are not high, as municipal and industrial wastes go, they are sig-

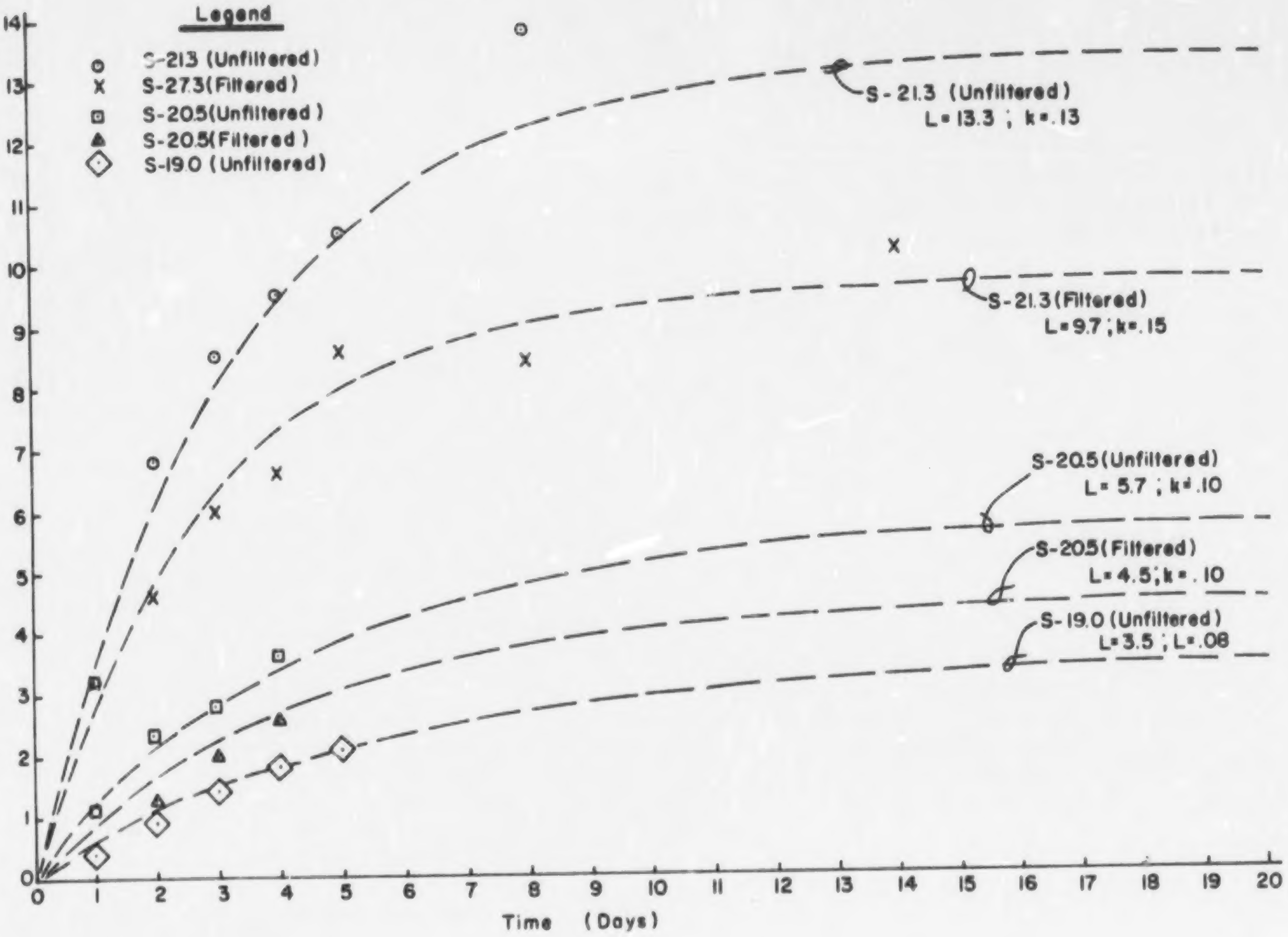


Figure 22. BOD survey below trout farm.

nificantly higher than those of the receiving stream. No meaningful cyclic tendencies were discovered in the BOD data from either effluent. Both discharges exhibit large, apparently random, deviations in BOD, the trout farm waste being erratic in this respect. BOD levels vary from 1.5 to 25.5 mg/l at the trout farm and from .4 to 9.0 at the Wellsville stream.

A BOD survey conducted on 29 August 1968, in the reach between the trout farm and Hyrum Reservoir, revealed a rather surprising rate of recovery from the load applied in the trout farm effluent. Three sampling points were studied, one immediately downstream from the point of discharge, a second 0.8 mile downstream and the third 2.3 miles downstream, just above Hyrum Reservoir. Travel time from the point of discharge (S-21.3) to the second sampling point (S-20.5) was estimated at 30 minutes while that from the second to third points was about one hour.

In this short time, the ultimate BOD of the unfiltered samples, as determined by the method of moments (Moore, Thomas, and Snow, 1950) dropped from 13.3 to 5.7 mg/l. The rate constant also decreased from 0.13 to 0.10 during this time, as mentioned previously and indicated in Figure 22. It is hypothesized that this rapid rate of recovery is brought about by the heavy Sphaerotilis growth found attached to the stony bottom (Figure 23). The density of this growth decreases rapidly in the downstream direction until it is hardly noticeable at the sampling point near Hyrum Reservoir. The results of this study are shown graphically in Figure 22. Analyses of filtered samples were conducted to determine whether or not the rapid change in BOD could be explained in terms of removal of suspended matter within the reach. BOD levels for filtered samples were found to be lower than those of unfiltered samples, but did not approach the low level observed at the downstream point. The luxurious growth on the gravel stream bed appears to act as a fixed bed

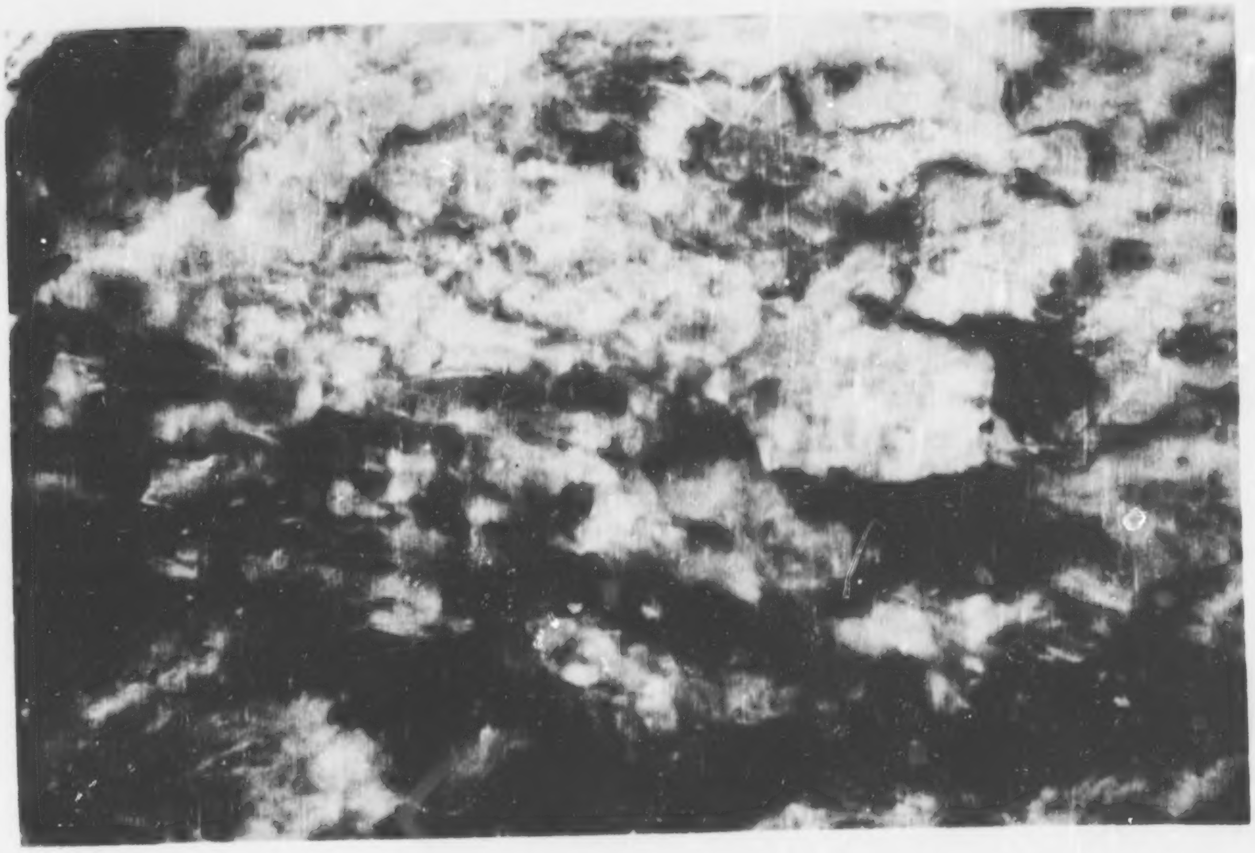


Figure 23. Sphaerotilis growth on rocks downstream from trout farm discharge.

reactor, quickly removing a large proportion of the organic matter carried into the stream by the trout farm discharge.

Combination of hydrologic inputs

Dissolved oxygen and BOD concentrations at the upstream end of the reach are calculated by the Equation 16 mixing formula. The deoxygenation rate constant of the combined flows is assumed to be the weighted average of the rate constants for all components of inflow, where the weighting factor is the total BOD contributed by each input:

$$K_1 = \frac{\sum_{j=1}^{nc} K_{1_j} \cdot q_j \cdot \overline{BOD}_j}{\sum_{j=1}^{n\,c} q_j \cdot \overline{BOD}_j} \quad . \; . \; . \; . \; (48)$$

in which

K_1 = deoxygenation rate constant of the combined inflow (base 10)
n = number of hydrologic inputs to the reach
K_{1j} = deoxygenation rate constant for the "j th" hydrologic input (base 10)
q_j = rate of flow for the "j th" hydrologic input
BOD_j = mean monthly BOD of the "j th" hydrologic input

The annual cycle

Mean daily dissolved oxygen exhibits an annual cycle. Figure 24 illustrates the pattern, which is sinusoidal. Simulation of this pattern is of value for its own sake to give the time distribution in dissolved oxygen at a given station; however, the value derived is also the initial D.O. input for the in-transit simulation. The annual D.O. simulation is the composite of the simulation of many individual inputs, described subsequently.

The simulation computer program for this phase is called MIDOX, implying monthly dissolved oxygen. This program, which is a part of the system program

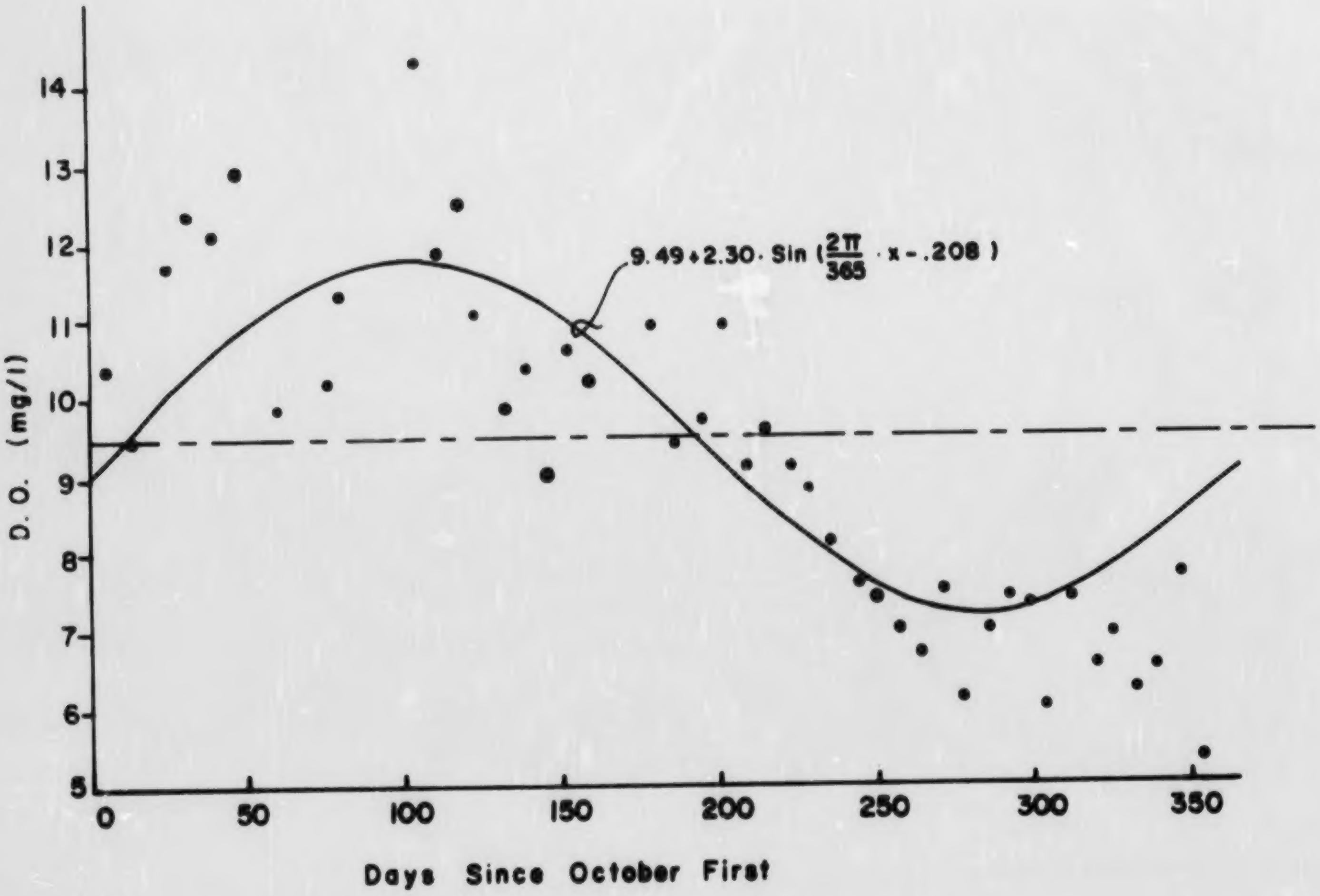


Figure 24. BOD variations at stations S-12.8 for 1966-67 with best fit Fourier series curve.

WAQUAL, also absorbs the "in-transit" and "diurnal" components; in aggregate then, MDISOX is the dissolved oxygen submodel.

Inputs

Adjustment of discrete sampling data. D.O. data from the weekly sampling program were adjusted for the effect of diurnal variation and varying sampling time by dividing by the diurnal D.O. index (DDOI) for the time at which the grab sample was taken. The DDOI is the ratio of observed D.O. concentration at the time of observation to mean daily concentration, as determined from continuous monitoring data. This adjustment considerably improved the fit of the annual cycle D.O. model over that attained using the raw D.O. data. Thus for all data discussed, which is to be representative of a single sample, it will be understood that the value reported is an adjusted mean daily value.

River inflow. The simulation procedure begins at the upper extremity of each branch, proceeding downstream. Results from the simulation of the adjacent upstream reach are employed as input for the simulation of the next reach downstream. For the first reach analyzed on a branch, the stream inflow is assumed to be zero and all natural surface inflows are lumped together in the "surface inflow" category (QS). The method of approximating D.O., BOD, and deoxygenation rate constant for this component is discussed below.

Branch inflow. Branches tributary to a reach are simulated before the analysis of that reach is attempted. The D.O., BOD, and deoxygenation rate constant of inflow from tributary branches are therefore available for incorporation into the analysis.

Surface inflow. Field data from analysis of weekly samples showed significant annual cycles for mean daily dissolved oxygen, with high values during winter months, which decreased to minimums in the summer and early fall. Figure 24 illustrates the trend using representative field data. The data were adjusted to mean daily values by dividing observed concentrations by the diurnal dissolved oxygen index (discussed later) for the time of sampling. A simple sine-curve linearizing equation:

$$\overline{DO} = \overline{\overline{DO}} + C \cdot \mathrm{Sin}\left(\frac{2\pi}{365} \cdot x + A\right) + \varepsilon \quad . . . . (49)$$

was fitted to the adjusted data by least squares analysis, where D.O. is mean daily dissolved oxygen concentration (mg/l) on the "x th" day of the year, D.O. is the mean annual D.O. concentration, x is the number of days since October 1, C and A are parameters determined by least squares regression procedures, and ε is the deviation of the oxygen concentration observed on the "x th" day of the year from the model prediction for that date. Fourier series containing more terms were tried, but without any significant improvement in fit. The model has been programmed, however, to allow a two term Fourier series should it be needed.

Table 14 lists the results of this Fourier series curve fitting at 12 sampling points on the system. The degree of fit, as measured by R^2, is not high, but statistical analyses indicate that Equation 31 does explain a significant portion of the total annual variation in D.O. at all stations. Figure 24 illustrates the relatively large residual deviations from the model. These variations appear to be random in nature, possibly resulting from random sampling errors and variations in oxygen concentrations caused by randomness in such controlling variables as water temperature and cloud cover.

Equation 49 has been adopted for the prediction of mean monthly D.O. concentrations in natural surface inflows despite the typically low R^2 because it does represent a significant cyclic annual variation at all points sampled.

In some cases, discernible annual cycles were also observed in the weekly BOD data (Figure 25). Therefore, a sine-curve equation, similar to that applied in the case of dissolved oxygen concentrations, was fitted to weekly BOD data from 12 sampling points in the Little Bear River drainage:

$$\overline{BOD} = \overline{\overline{BOD}} + C \cdot \mathrm{Sin}\left(\frac{2\pi}{365} \cdot x + A\right) + \varepsilon \quad . . . . (50)$$

As shown in Table 15, the degree of fit varied considerably from one location to another. Statistical significance could be claimed for eight of the twelve sets of data.

Though the degree of correlation between time of year and BOD concentration was not high, a significant portion of the total variation at a majority of the sampling points was explained by Equation 50. Because a better procedure for predicting BOD concentrations in surface inflows was not forthcoming, Equation 50 has been incorporated into the simulation to approximate annual cycles for the BOD of natural surface inflows.

Irrigation return flow. Dissolved oxygen concentrations in surface irrigation return flows are assumed relatively constant over the three or four month irrigation season, though provision is made in the modeling program to allow variation with time.

The BOD of return flow is also considered constant. Because waters applied to agricultural lands have more opportunity to pick up organic matter from animal and vegetal matter in and on the soil, the level of oxygen demand in return flows is assumed to be somewhat above that found in natural surface inflows. The deoxygenation rate constant for irrigation return flows is assumed to be the same as that for natural surface inflows.

Groundwater inflow. Dissolved oxygen concentrations in groundwater inflows were not sampled during

Table 14. Fourier series simulation of annual fluctuations in dissolved oxygen concentration.

$$\left[\overline{DO} = \overline{\overline{DO}} + C \cdot \mathrm{Sin}\left(\frac{2\pi}{365} \cdot x + A\right)\right]$$

Station	$\overline{\overline{DO}}$ (mg/l)	C (constant)	A (radians)	R^2 (%)	Comments
S-12.7	8.55	1.517	-.407	56.	below sewer outfall
S-12.8	9.49	2.303	-.208	66.	
S-15.2	9.97	1.808	-.573	36.	
S-16.8	8.77	1.863	-.897	74.	reservoir surface
S-21.3	7.23	1.591	-.660	61.	below trout farm
S-24.6	8.95	1.321	-.148	60.	
S-27.5	8.61	1.032	-.247	52.	
SD-0.0	8.82	1.896	-.401	62.	
SEC-4.3	8.59	.998	-1.243	27.	below reservoir
SEC-6.2	8.48	1.163	-.394	62.	
STF-0.0	6.35	1.520	-.773	31.	trout farm effluent
SW-0.1	8.08	1.126	-.425	62.	sewer outfall

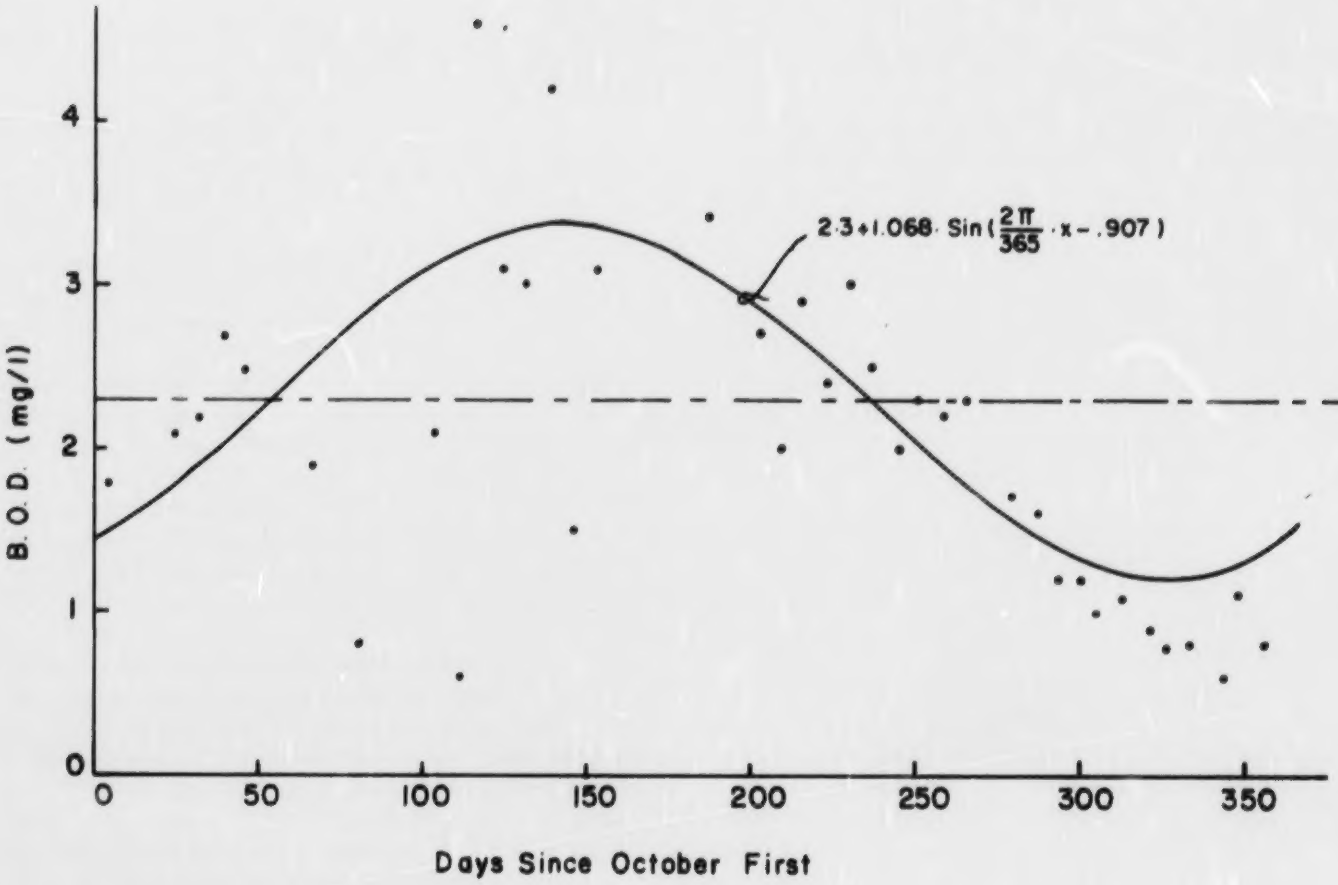


Figure 25. Annual BOD cycle, station S-12.8.

Table 15. Fourier series modeling of annual variations in BOD (5 day, 20°C).

$$\left[\overline{\mathrm{BOD}} = \overline{\mathrm{BOD}} + C \cdot \mathrm{Sin}\left(\frac{2\pi}{365} \cdot x + A\right)\right]$$

Station	BOD (mg/l)	C (constant)	A (radians)	R^2 (%)	Comments
S-12.7	2.5	.956	-1.048	30.[a]	below sewer outfall
S-12.8	2.3	1.068	- .907	32.[a]	
S-15.2	2.6	1.022	- .937	23.[a]	
S-16.8	2.9	1.617	- .171	21.[a]	reservoir surface
S-21.3	6.8	1.772	-1.553	16.	below trout farm
S-24.6	1.7	.485	- .690	13.	
S-27.5	1.7	.897	-1.154	43.[a]	
SD-0.0	1.9	1.002	- .813	50.[a]	
SEC-4.3	1.6	.898	-1.272	62.[a]	below reservoir
SEC-6.2	1.8	1.022	- .930	30.[a]	
STF-0.0	8.9	3.301	3.820	17.	trout farm effluent
SW-0.1	3.8	.986	4.353	12.	sewer outfall

[a] Statistically significant at the α = .05 level.

this project. A sinusoidal pattern of annual variation, similar to that found in natural surface inflows, was assumed for groundwater inflows.

Biochemical oxygen demand of groundwater was not measured, but is assumed to be zero. This assumption is based upon the ability of the biologically active soil mantle to stabilize dissolved organics as the water passes through enroute to the groundwater aquifer. Suspended organics are removed by the screening action of soil particles. For modeling purposes, the BOD of groundwater inflows is taken as zero.

Municipal and industrial releases. Annual variations in municipal and industrial releases are simulated by card input based upon historical records where possible.

Summary. Table 16 summarizes the simulation for each hydrologic input. The stream is considered reach by reach along the main stem and immediate tributaries; all or part of these inputs may be significant for any given reach. The mean daily dissolved oxygen value, D.O., for that reach is calculated by the weighted average of all inputs.

Reservoir effects

Of the two reservoirs on the Little Bear River, only Porcupine Reservoir was sampled to assess the effect of the impoundment on the oxygen resource of the stream. Dissolved oxygen concentrations at the sampling point immediately below Porcupine Reservoir were consistently at or near the level of saturation as indicated in Figure 26. This is reasonable for this situation, even though releases from this reservoir are from the hypolimnion, because of the intense turbulence in the discharge stilling basin.

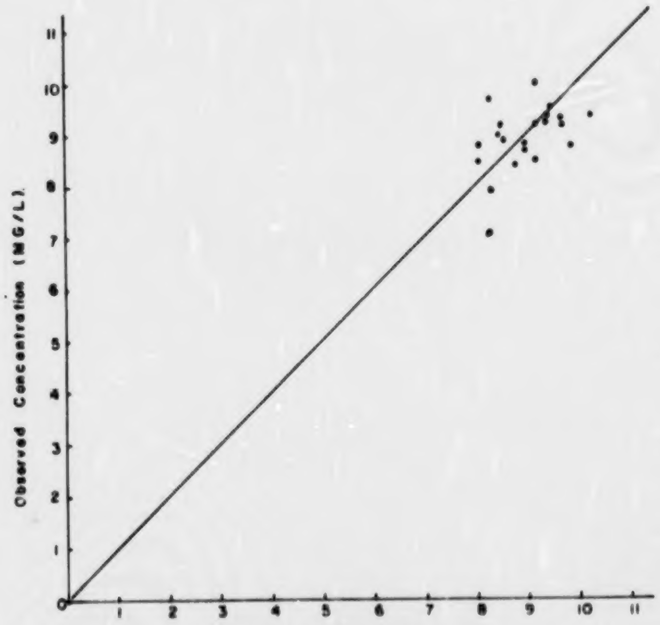


Figure 26. Comparison of D.O. concentrations observed below Porcupine Reservoir in 1967 with saturation concentration.

Therefore a simulation run was made with the D.O. in the reservoir discharge set equal to the saturation concentration. This assumption resulted in significant deviations of simulated concentrations from measured values, both at the reservoir discharge and at points downstream.

Time series analysis of weekly D.O. data from Porcupine Reservoir discharge disclosed a small, but statistically significant correlation between time of year, and D.O. concentration, represented by the equation

$$\overline{DO}_r = \overline{\overline{DO}}_r + C_r \cdot \mathrm{Sin}\left(\frac{2\pi}{365} \cdot x + A_r\right) + \varepsilon \quad . . (51)$$

This time series equation improved the correspondence between simulated and measured D.O. concentrations at reservoir discharges and at points downstream. Therefore, Equation 51 was used to simulate D.O. concentrations in reservoir releases, rather than to assume saturation.

Because of the high degree of randomness in the BOD data, it was difficult to determine precisely what hydrologic or hydraulic parameters relate best to the BOD load in released water. Again, some degree of time dependence was observed. A simple sine-curve representation of monthly variations in BOD at reservoir releases was incorporated into the simulation model.

To summarize: monthly variations in D.O. and BOD of reservoir releases were both assumed to follow a sinusoidal pattern through the annual cycle. The annual mean, coefficient, C, and phase shift, A, were determined by the least squares fitting of Equation 51 to observed D.O. and BOD data for the reservoir release.

Simulation algorithm

Figure 27 outlines the simulation algorithm for mean monthly dissolved oxygen. This algorithm is summarized below.

1. Obtain monthly flow values for all inputs listed in Table 16 from the hydrologic model.
2. Establish mean annual D.O., and Fourier constants, A and C, for Equation 49 by regression analysis of field data; do likewise for Equation 50.
3. Compute D.O. and BOD of each input to reach for month in question by Equations 49 and 50, respectively; use card input where these equations are not applicable.
4. Compute stream D.O., consisting of combined inflows, by Equation 16.
5. If each is a reservoir, calculate output D.O. by Equation 15, skipping steps 6, 7, 8, 9, 10, 11, 12, 13.
6. Compute weighted deoxygenation rate constant, k_1, by Equation 48, and correct for temperature by Equations 46 and 47.
7. Estimate the reoxygenation rate constant, k_2, using Equation 44 and adjust for temperature by Equation 45.

8. Calculate saturation concentration for reach using output of temperature simulation as argument for Equation 42; also adjust for altitude pressure by Equation 43; alternately, Figure E-2 may be used.

9. Calculate oxygen deficit at the upstream end of the reach ($D_a = C_{s_a} - DO_a$) and apply the sag equation (Equation 32).

10. Subtract the remaining deficit from the saturation concentration at the downstream end of the reach to estimate the dissolved oxygen concentration at the outflow from the reach.

11. Determine residual BOD in reach outflow (Equation 36).

12. Compute areal BOD of the benthos at the end of the month (Equation 34 or 41).

13. Call diurnal submodel if desired.

14. Go to next reach and return to step 1.

15. If last reach is simulated, increment time by one month and return to step 1.

Step 2 is input preparation; steps 1, 13, 14, and 15 are done by WAQUAL; steps 3-12 are done by DDISOX.

Table 16. Summary of input D.O. and BOD equations over the annual cycle.[a]

Input	Parameter	Model
River inflow	D.O.	result from previous simulation
	BOD	
	K_1	
Branch inflow	D.O.	result from previous simulation
	BOD	
	K_1	
Surface inflow	D.O.	$\overline{DO_s} = \overline{\overline{DO_s}} + C \cdot \mathrm{Sin}\left(\frac{2\pi}{12} \cdot m + A\right)$
	BOD	$\overline{BOD} = \overline{\overline{BOD}} + C \cdot \mathrm{Sin}\left(\frac{2\pi}{12} \cdot m + A\right)$
	K_1	card input
Irrigation return flow	D.O.	$\overline{DO_i} = \overline{\overline{DO_i}} + C \cdot \mathrm{Sin}\left(\frac{2\pi}{12} \cdot m + A\right)$
	BOD	card input
	K_1	
Groundwater inflow	D.O.	$DO_g = DO_g + C \cdot \mathrm{Sin}\left(\frac{2\pi}{12} \cdot m + A\right)$
	BOD	card input
	K_1	
Municipal and industrial release	D.O.	card input
	BOD	
	K_1	

[a] Submodel constants ($\overline{\overline{DO}}$ and $\overline{\overline{BOD}}$), coefficients (C) and phase shifts (A) are determined by analysis of field data and provided to the simulation program by punched card input.

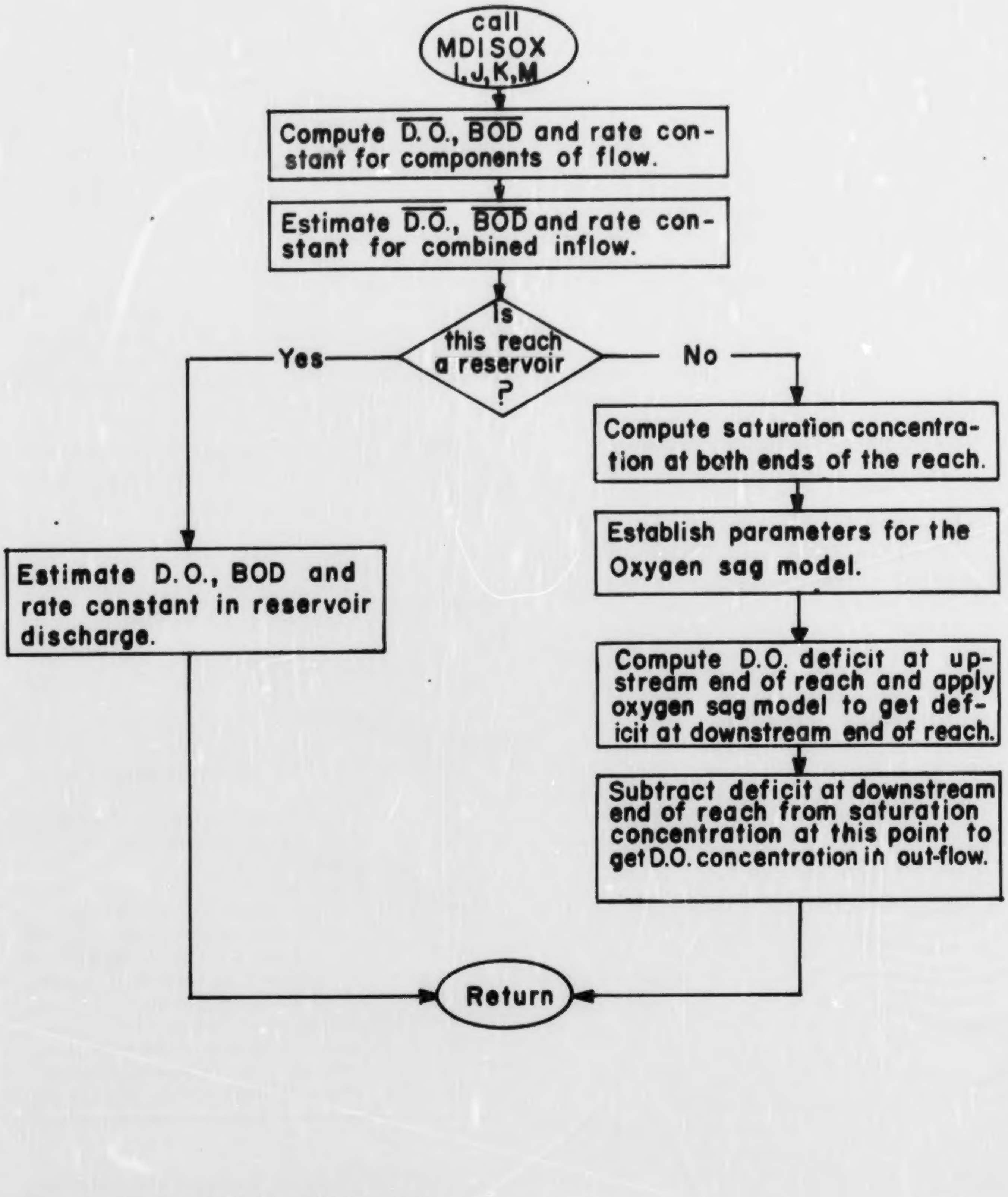

call
MDISOX
I,J,K,M
Compute $\overline{D.O.}$, $\overline{BOD}$ and rate constant for components of flow.
Estimate $\overline{D.O.}$, $\overline{BOD}$ and rate constant for combined inflow.
Is this reach a reservoir ?
Yes
No
Estimate D.O., BOD and rate constant in reservoir discharge.
Compute saturation concentration at both ends of the reach.
Establish parameters for the Oxygen sag model.
Compute D.O. deficit at upstream end of reach and apply oxygen sag model to get deficit at downstream end of reach.
Subtract deficit at downstream end of reach from saturation concentration at this point to get D.O. concentration in out-flow.
Return

Figure 27. Generalized monthly D.O. flow chart.

Diurnal dissolved oxygen

Several observers have reported diurnal variations in dissolved oxygen concentrations in natural streams. Hoak and Bramer (1961) found relatively minor diurnal cycles in D.O. in several Pennsylvania streams. Gunnerson and Bailey (1963), however, report significant daily variation in D.O. along the Sacramento River from Redding to the delta. O'Connell and Thomas (1965), in reporting their studies of the Truckee River in Nevada, indicate relatively large diurnal fluctuations in D.O. These fluctuations were attributed to the activity of photosynthetic organisms attached to the stream bottom.

Frankel (1965), in discussing the cyclic pattern of deviations from mean daily dissolved oxygen, proposes a photosynthetic factor for each reach. This factor is a function of the time of day, and is defined in terms of the ratio of hourly D.O. to mean daily D.O. Thomann (1967), in his study of the Potomac estuary, found significant diurnal fluctuations in D.O. only above the zone of tidal influence.

Many comments found in the literature emphasize the importance of considering these diurnal variations, but surprisingly little has been published concerning their characterization. As with temperature, a single measurement is not representative of the stream. To assess the dissolved oxygen quality of a stream, it is imperative that the diurnal effect be characterized. It is the purpose of this section to ascertain the mathematical description of the diurnal dissolved oxygen fluctuations. As with temperature, the monthly effect on the diurnal variation is also defined. This is done using continuous monitoring field data from station S-12.5, located below Wellsville on the Little Bear River. A sample of these data is shown in Figure 28.

Modeling diurnal dissolved oxygen variations

Nineteen blocks of continuously monitored dissolved oxygen data, varying from 3 to 7 days in length and covering an 18-month period, have been fitted, as described in Appendix D, with a two term Fourier series of the form

$$DO_i = \overline{DO} + \sum_{j=1}^{2} C_j \cdot \mathrm{Sin}\left(\frac{2\pi}{24} \cdot j \cdot i + A_j\right) + \varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots (52)$$

in which

DO_i = D.O. concentration (mg/l)

$\overline{DO}$ = average mean daily oxygen concentration (mg/l) for the time period covered by the block of continuous data being fitted

C_j = coefficient of the "j th" term

A_j = phase shift for the "j th" term

ε_i = deviation from the model

i = hour of the day

The two-term model provides essentially the same fit as did three- and four-term series. This fit was considerably better than that obtained from the one-term model. Figure 28 depicts a typical set of hourly D.O. observations over a 7-day period, with the best-fit two-term Fourier series model superimposed.

Two interesting characteristics of this typical diurnal pattern should be noted. First, notice the time period during which D.O. concentrations are typically higher than average. For this particular set of data it runs from 8:00 a.m. through 6:00 p.m. (the hours during which water quality samples are usually taken). This factor results in an upward bias of most "grab sample" stream D.O. data. Another characteristic is the long flat region in the curve, extending from about 9:00 p.m. through 5:00 a.m. During this 8-hour period, the D.O. concentration is 2 mg/l lower than a sample taken at 1:00 p.m. would have indicated. The importance of considering diurnal D.O. variations is obvious.

Dividing Equation 52 through by mean daily D.O. yields a defined term, called the diurnal dissolved oxygen index (DDOI):

$$DDOI_i = 1.0 + \sum_{j=1}^{2} C_j \cdot \mathrm{Sin}\left(\frac{2\pi j}{24} \cdot i + A_j\right) + \varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots (53)$$

in which

$DDOI_i$ = $DO_i / \overline{DO}$, diurnal dissolved oxygen index

C_j = coded coefficient of the "j th" term

A_j = phase angle of the "j th" term

ε_i = coded error term

i = hour of the day

In Equation 53, the coefficient, C_j, and error term, ε_i are now coded by division by mean daily D.O. The resulting coefficients and phase shifts are shown in Table 17, along with the coefficient of determination (R^2), average D.O. and average atmospheric temperature for the period covered by each block of continuous data. Annual cyclic tendencies may be detected in the tabulated model parameters. The cyclic variations become more evident when the DDOI model parameters (C_1, C_2, A_1 and A_2) of Equation 53 are plotted versus time of year as shown in Figure 29.

Equation 54 augments Equation 53 by representing the annual cycles in the A_j and C_j parameters:

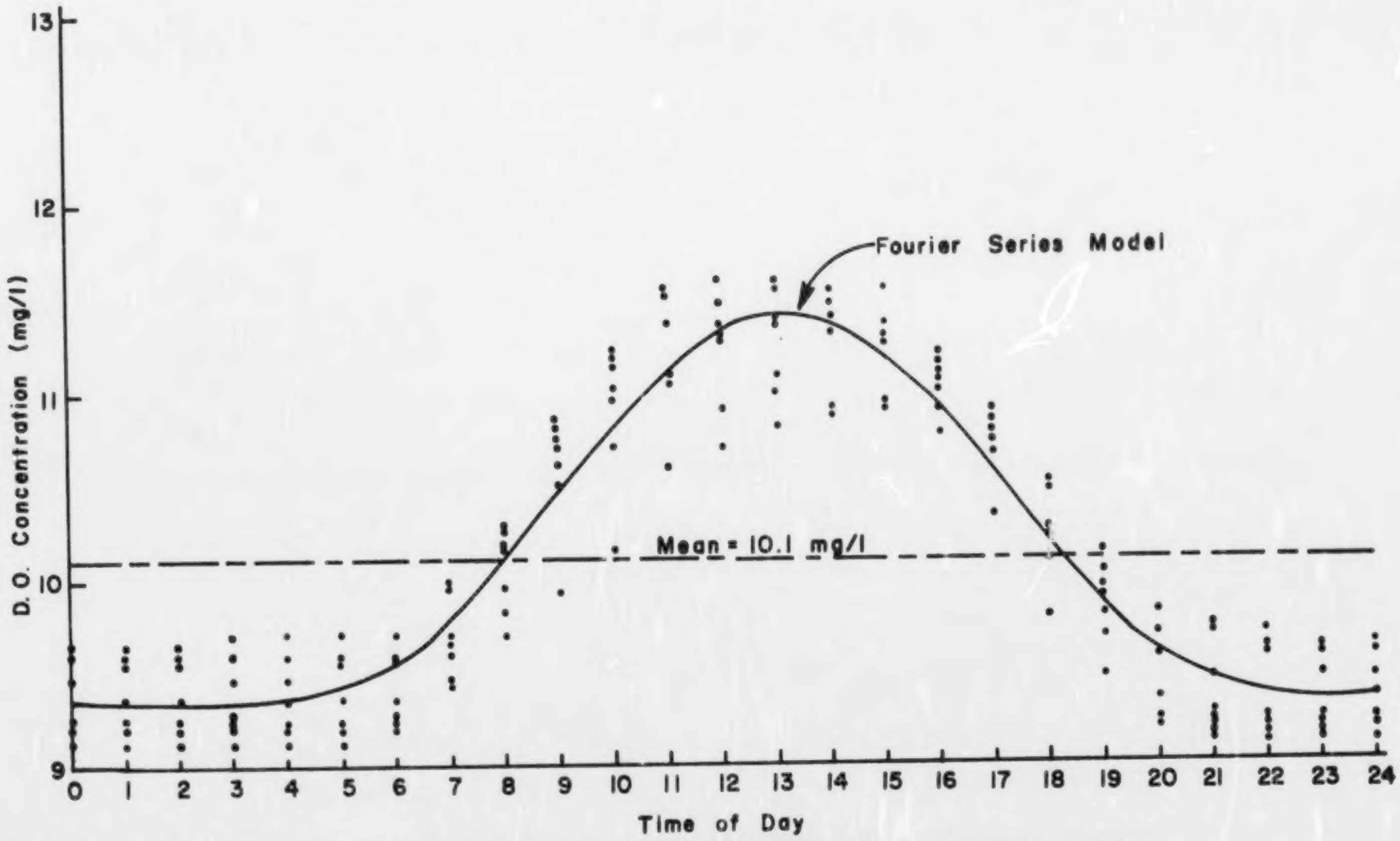


Figure 28. Dissolved oxygen variations for the period 22-29 April 1968 with Fourier series model.

Table 17. Diurnal dissolved oxygen index model parameters.

$$\left[DDOI_i = 1.0 + \sum_{j=1}^{2} C_j \cdot \mathrm{Sin} \left(\frac{2\pi j}{24} \cdot i + A_j \right) \right]$$

Date	No. of days	C_1 (constant)	A_1 (radians)	C_2 (constant)	A_2 (radians)	R^2 (%)	DO	T_a	Notes
1127-120167	4	.0767	4.405	.0400	.844	74.	10.0	26.8	
222-22968	6	.0304	4.777	.0144	1.287	67.	11.3	35.2	
229-30668	6	.0284	4.829	.0117	1.205	53.	11.0	39.2	
318-32568	7	.0596	4.865	.0220	1.032	66.	9.9	36.8	
325-32868	3	.0666	4.868	.0295	1.013	87.	9.5	42.8	
404-40668	2	.0196	4.483	.0047	.723	73.	10.0	40.5	Rain
417-42268	5	.0752	4.518	.0220	1.211	80.	9.9	35.2	
422-42968	7	.0999	4.422	.0271	.956	91.	10.1	42.8	
517-52468	7	.1197	4.307	.0302	.734	61.	7.9	52.6	
524-53168	7	.1542	4.169	.0364	.612	67.	8.5	55.7	
531-60468	4	.2060	4.194	.0564	.275	83.	7.3	59.3	
606-61268	6	.0450	4.104	.0082	-.114	60.	9.3	56.8	Rain
624-62768	3	.2005	4.457	.0481	.450	94.	7.6	63.7	
1004-100668	2	.0921	4.468	.0503	.251	55.	9.2	53.7	
1009-101368	4	.1053	4.315	.0560	.350	91.	8.6	54.5	
1023-102968	7	.0736	4.448	.0429	.675	89.	9.3	47.7	
1030-110568	7	.0690	4.374	.0396	.521	74.	9.6	42.4	
1106-111068	5	.0995	4.455	.0567	.814	89.	10.2	38.5	
1203-121068	7	.1008	4.399	.0588	.787	94.	12.1	29.3	

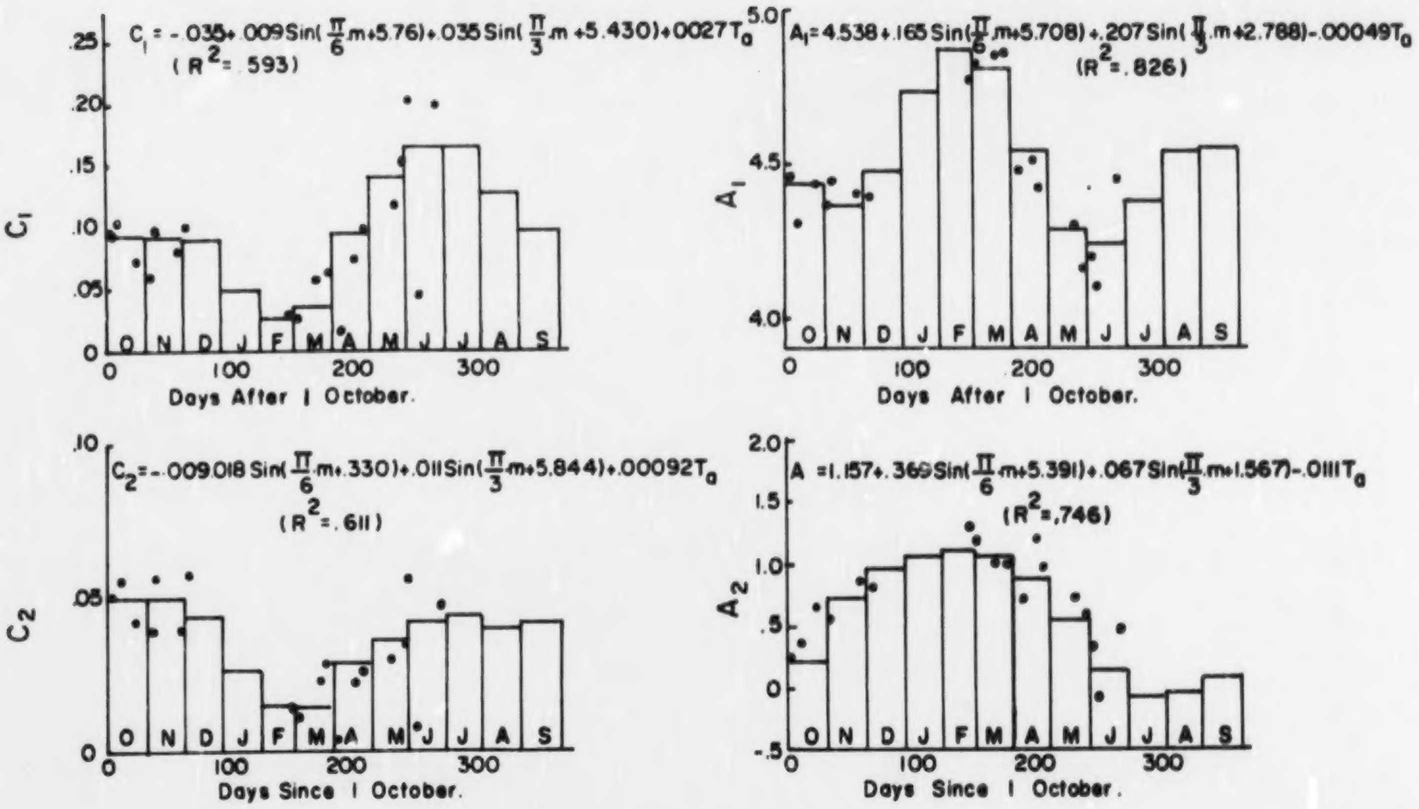


Figure 29. Annual variation in diurnal D.O. index model parameters.

$$Y = c_o + \sum_{j=1}^{2} c_j \cdot \text{Sin}\left(\frac{2\pi j}{365} \cdot x + a_j\right) + \overline{T}_a + \varepsilon \quad \ldots\ldots\ldots\ldots\ldots\ldots (54)$$

in which

Y = diurnal D.O. index model parameter (A_1, A_2, C_1 or C_2)
x = days since 1 October
$\overline{T}_a$ = mean daily atmospheric temperature (°F)
ε = deviation of predicted diurnal D.O. model parameter from that calculated from diurnal D.O. variations observed
c_o, c_j, and a_j = constant, coefficient and phase shift, respectively as determined from least squares analyses of diurnal data blocks

Equations 53 and 54 comprise the augmented Fourier series simulation equations for diurnal dissolved oxygen. Table 18 shows the constant, c_o, coefficient, c_j, and phase shift, a_j, for an annual cycle; these values were determined by least squares analysis of the data blocks indicated in Table 17 for A_1, A_2, C_1, and C_2 respectively. From this analysis of Table 17 data blocks, the annual cycle in C_o, C_j, and A_j is assigned monthly values which are shown in Table 19; the Table 19 values were calculated by Equation 54 using coefficients from Table 18. Figure 29 shows a comparison of the application of these assigned monthly values, indicated by the bar lengths, to values from the data block analyses shown in Table 17, and indicated as plotted points in Figure 29.

Graphical representation of the diurnal dissolved oxygen index (DDOI), Equation 53, for each month of the year is shown in Figure 30. These curves display the patterns of D.O. variation to be expected for each month of the year. Seasonal differences in the relative magnitudes of daily D.O. swings are also shown. A phase shift of about two hours in time appears between the curves, representing winter and early spring months and those for summer months. Considerable deviation from this "typical" pattern should be expected during periods of extensive cloud cover.

Hourly estimates of dissolved oxygen concentration may be made by multiplying the hourly ordinates to the DDOI curve by mean daily D.O. In the simulation procedure, the mean daily D.O. concentration is taken as the same as the mean monthly value provided by the monthly D.O. simulation model.

Table 18. Representation of annual changes in diurnal D.O. index model parameters.

$$\left[Y = c_o + \sum_{j=1}^{2} c_j \cdot \mathrm{Sin}\left(\frac{2\pi}{365} \cdot x + a_j\right) + \overline{T}_a \right]$$

Parameter	c_0 (constant)	c_1 (constant)	a_1 (radians)	c_2 (constant)	a_2 (radians)	r (radians)	R^2 (%)
$Y = C_1$	-.035	.009	5.746	.035	5.430	.0027	59.
$Y = A_1$	4.538	.165	5.708	.201	2.788	-.0005	83.
$Y = C_2$	-.009	.018	.330	.011	5.844	.0009	61.
$Y = A_2$	1.157	.369	5.394	.067	1.567	-.0111	75.

Table 19. Estimated monthly values of diurnal D.O. index model parameters by Equation 54 using coefficients from Table 18.

Month	C_1 (constant)	A_1 (radians)	C_2 (constant)	A_2 (radians)
October	.0900	4.428	.0496	.428
November	.0877	4.366	.0503	.717
December	.0827	4.479	.0443	.931
January	.0491	4.717	.0272	1.132
February	.0276	4.873	.0159	1.206
March	.0366	4.796	.0154	1.142
April	.0932	4.529	.0292	.867
May	.1388	4.287	.0373	.566
June	.1667	4.241	.0416	.235
July	.1666	4.379	.0436	-.017
August	.1280	4.530	.0403	-.010
September	.0948	4.539	.0420	.177

Diurnal patterns of hydrologic inputs

Diurnal patterns of D.O. variation for each of the various hydrologic inputs to a given stream reach must be known in order to simulate hourly changes in dissolved oxygen concentration for that reach. The diurnal index concept analysis is the basis for doing this.

Surface inflow. The diurnal dissolved oxygen index simulation of the Wellsville continuous monitoring station is assumed to represent the hourly variation in D.O. in all natural surface inflows to the system. Figure 31 compares the index patterns for the Wellsville and Paradise continuous monitoring stations; though the correspondence is not one to one, it does indicate at least a reasonable similarity and indicates the order of magnitude of possible deviations. Spot checks on the Little Bear River system have also confirmed this degree of confidence.

Hourly D.O. concentrations in surface inflows are approximated by multiplying the index value for each hour of the day by the mean monthly D.O. concentration for the input stream. Mean monthly D.O. is taken as previously calculated by the monthly D.O. model. BOD and deoxygenation rate constants are assumed to be constant over the "typical" 24 hour period. These variables are evaluated in the monthly D.O. model.

Irrigation return flow. The lack of data on surface irrigation return flows prevents any authoritative assertion as to the pattern of diurnal D.O. variation to be expected in this input. The extent of photosynthetic activity in the return flow stream would depend on the nature of the channel and upon stream turbidity. Both of these factors are expected to be highly variable. For example, return flows from well stabilized hay and pasture land would be expected to be relatively low in turbidity, while those from more extensively cultivated croplands (row crops

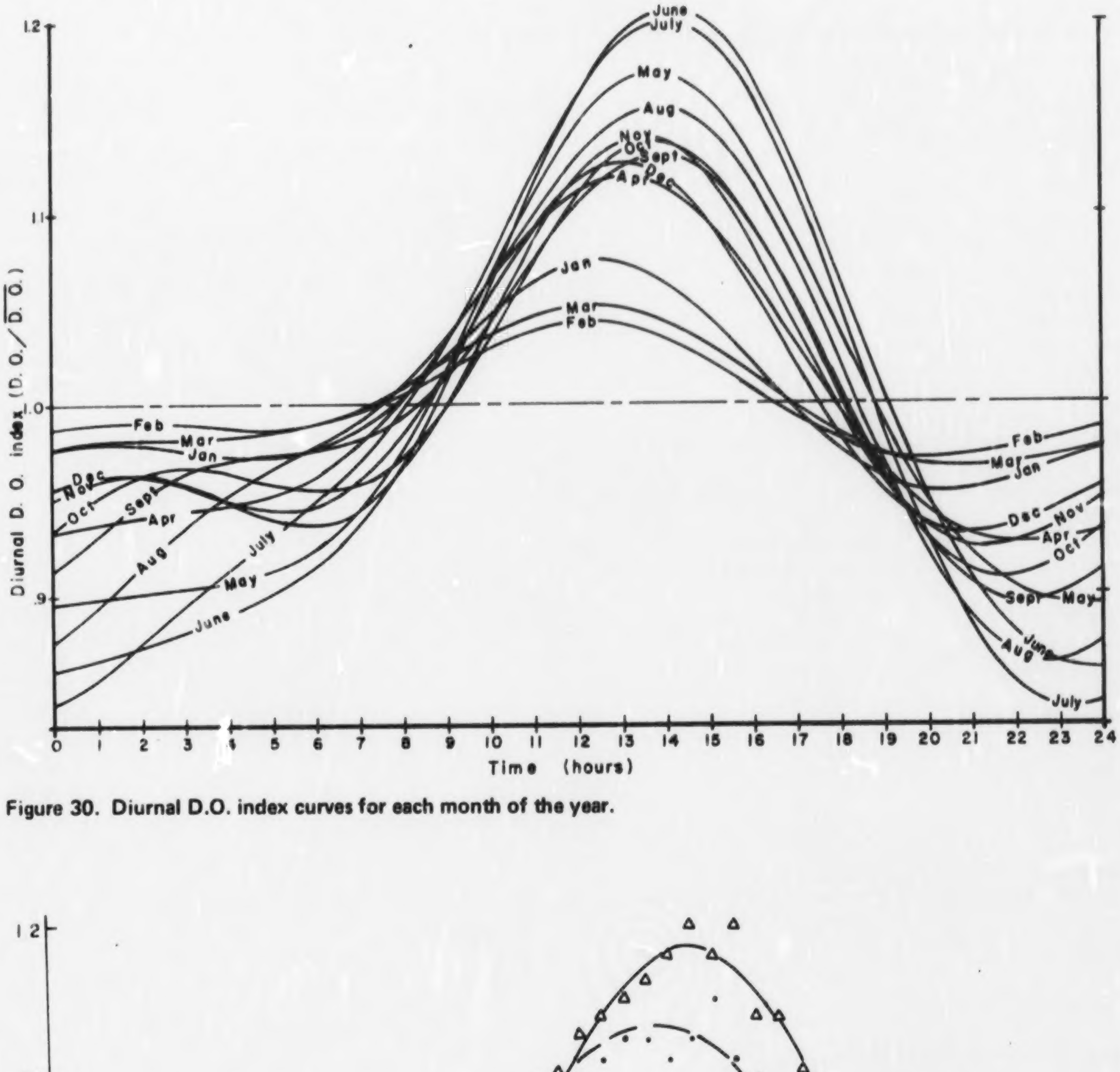


Figure 30. Diurnal D.O. index curves for each month of the year.

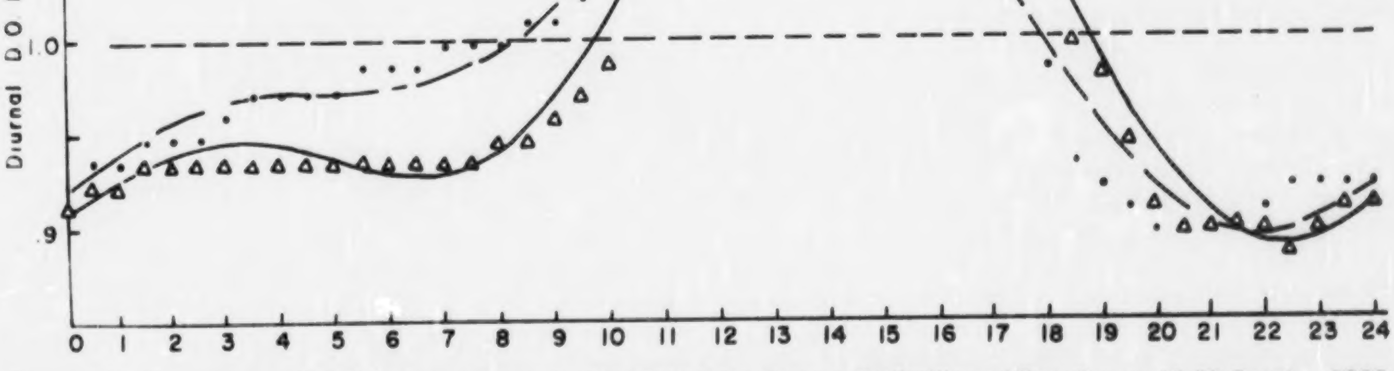


Figure 31. Comparison of D.O. index patterns on the Little Bear River at Wellsville and Paradise on 11-12 October 1968.

and grains) would carry heavier silt loads with resulting high turbidity levels. These high levels of turbidity hinder the passage of light into the water, thus effectively limiting photosynthetic activity. In many instances, however, irrigation return flows pass through quiescent pools and sloughs enroute to the river, so that ample opportunity is afforded for sedimentation and subsequent reestablishment of the photosynthetic process. Despite these uncertainties, hourly variations in irrigation return flow dissolved oxygen are assumed to follow the diurnal D.O. index pattern.

Groundwater inflow. Inputs originating from subsurface flows are assumed to exhibit no daily fluctuations in dissolved oxygen content. The BOD of groundwater inflows is taken to be zero.

Municipal-industrial releases. Dissolved oxygen concentrations in municipal or industrial discharge streams may vary diurnally, depending upon the scheduling of process work, type of treatment provided, organic and hydraulic loading of treatment facilities, and whether or not there is an opportunity for photosynthetic activity in the waste treatment or discharge systems. Fair, Geyer, and Okun (1968) suggest the patterns depicted in Figure 32 as typical of flow and organic load variation for domestic waste water streams. Treatment of the waste may result in modifications of these distributions. The quantity and strength of industrial wastes also may vary considerably on an hourly basis.

The specific pattern is unique to the situation; thus hourly variations of quantity, BOD and D.O. must be provided as input to the simulation program for each waste stream entering the system.

Combination of inputs. Dissolved oxygen concentrations, BOD and deoxygenation rate constant are determined for the hour-by-hour combination of inflow components to obtain a weighted average for the stream, which can be accomplished again by the use of Equation 16.

Reservoirs

Dissolved oxygen concentrations in reservoir releases are assumed to be constant and equal to the mean monthly value determined from the monthly D.O. model.

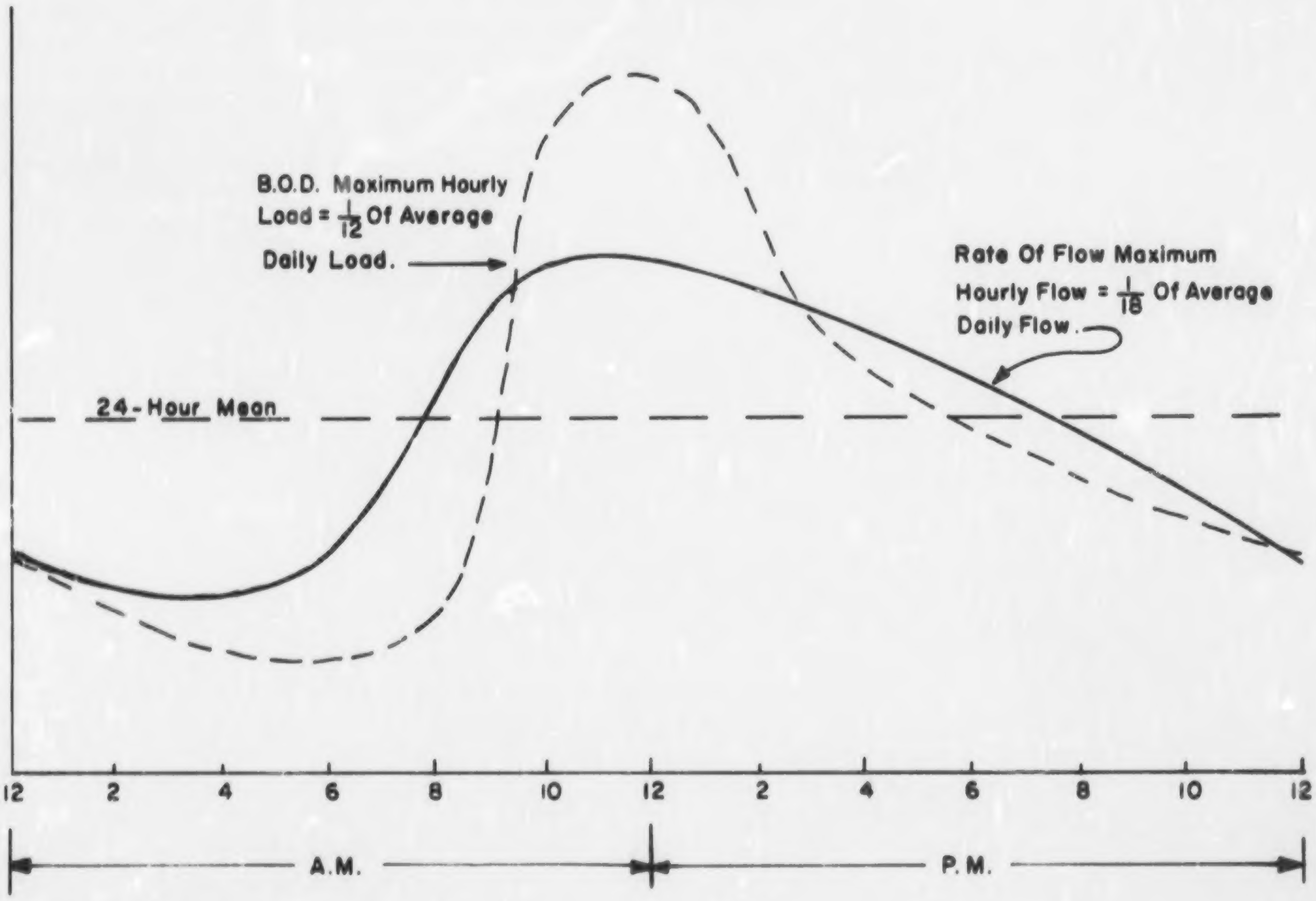


Figure 32. Flow and strength variations in domestic waste.

In-transit changes and the diurnal effect

The effect of a discrete waste input on the stream is assessed by the dissolved oxygen sag Equation 32, as discussed previously. For a realistic assessment, however, the photosynthesis-respiration effects must also be considered. This is done herein by superposing one result upon the other as shown in Figure 33, in terms of a hypothetical example problem. The corresponding steps are outlined as follows. The diurnal dissolved oxygen behavior at two ends of a stream reach is simulated for a waste input at the upper end.

1. At upstream end of reach, determine and input hourly stream values of D.O., BOD, and k_1, as shown in Figure 33a.
2. Obtain hourly distribution of D.O. and BOD for the waste input, as shown in Figure 33b.
3. Calculate weighted average of D.O. and BOD for streamflow mixed with waste for each hour to obtain the two lower curves shown in Figure 33c. From the diurnal temperature distribution, calculate the diurnal distribution in saturation concentrations, which is the top curve of Figure 33c. The deficit distribution is the amplitude of the cross hatched area.
4. Obtain the travel time through the reach, tt. Calculate D.O. deficit, D_b, at downstream end of reach for each hour of day (incremented by travel time, tt) by Equation 32, using hourly values of D_a from Figure 33c as successive arguments.
5. Obtain the saturation distribution for the downstream end of the reach; this is the top curve in Figure 33d. Subtract from this the calculated deficits, D_b, to get the D.O. distribution devoid of the effects of photosynthesis and respiration.
6. The photosynthesis-respiration activity in a reach is represented by the equation:

$$O_p = Pf \cdot (DDOI - 1.0) \quad . . . . (55)$$

in which

O_p = oxygen produced by photosynthetic organisms (negative for respiration)

DDOI= diurnal dissolved oxygen distribution

Pf = productivity factor

The "productivity factor," as used in this simulation, is a scaling factor, applied to the diurnal dissolved oxygen index distribution to represent the activity of photosynthetic organisms within the reach being simulated.

Application of Equation 55 results in the lower sine curve of Figure 33d.

7. Adding the result of step 6 to the result of step 5 results in the *net* dissolved oxygen distribution curve, also shown in Figure 33d.

Simulation algorithm

Figure 34 outlines the steps necessary to simulate representative diurnal variations in dissolved oxygen for any given month or months specified. This algorithm works for the main stem or any branch of the main stem. The effect of BOD loadings is simulated by an hour by hour application of the oxygen sag equation to obtain the D.O. effect at the downstream end of the reach. After the reaches in the main stem and branches are simulated, time is incremented by one month and the simulation is repeated.

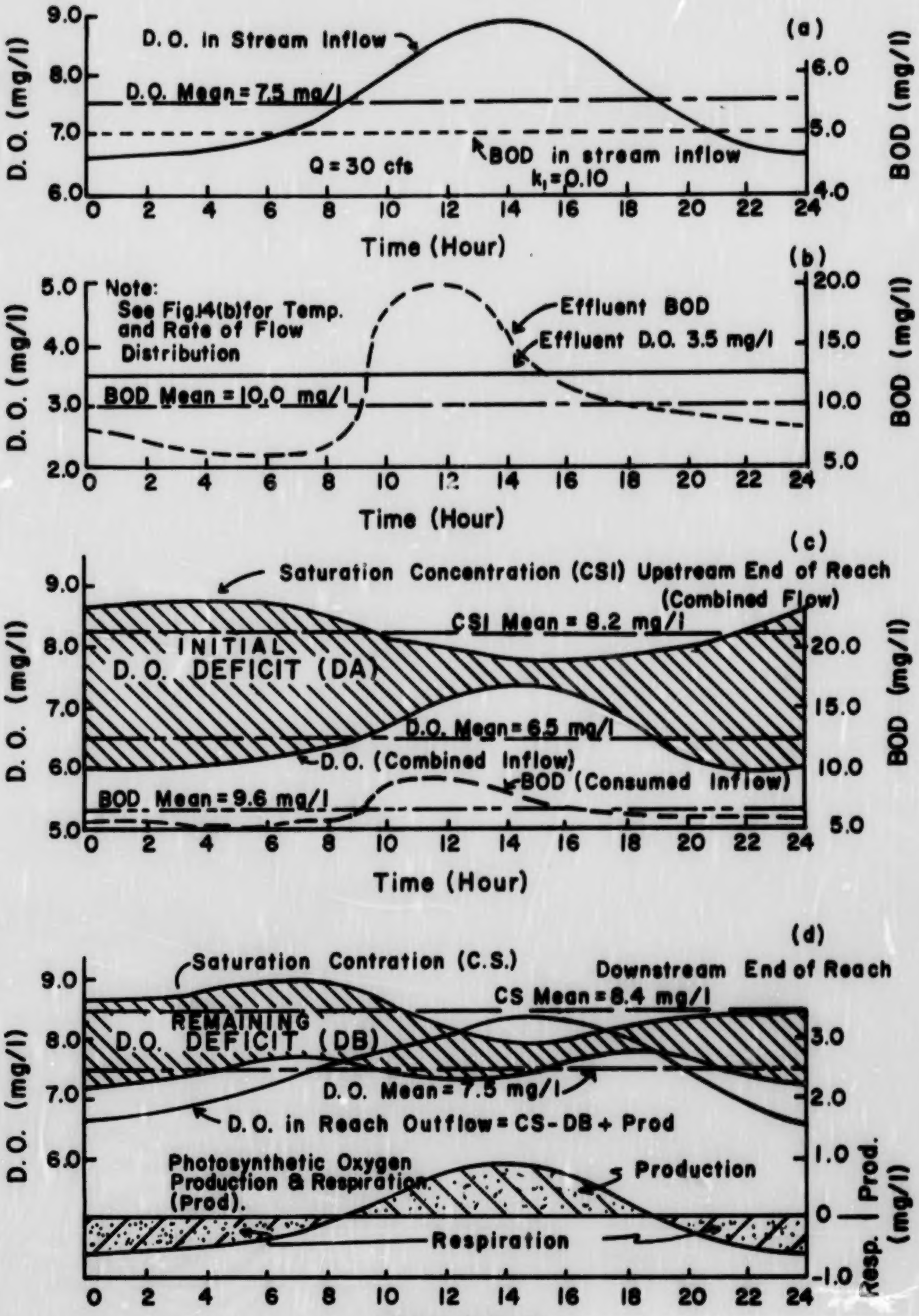


Figure 33. Graphical representation of diurnal D.O. computation.

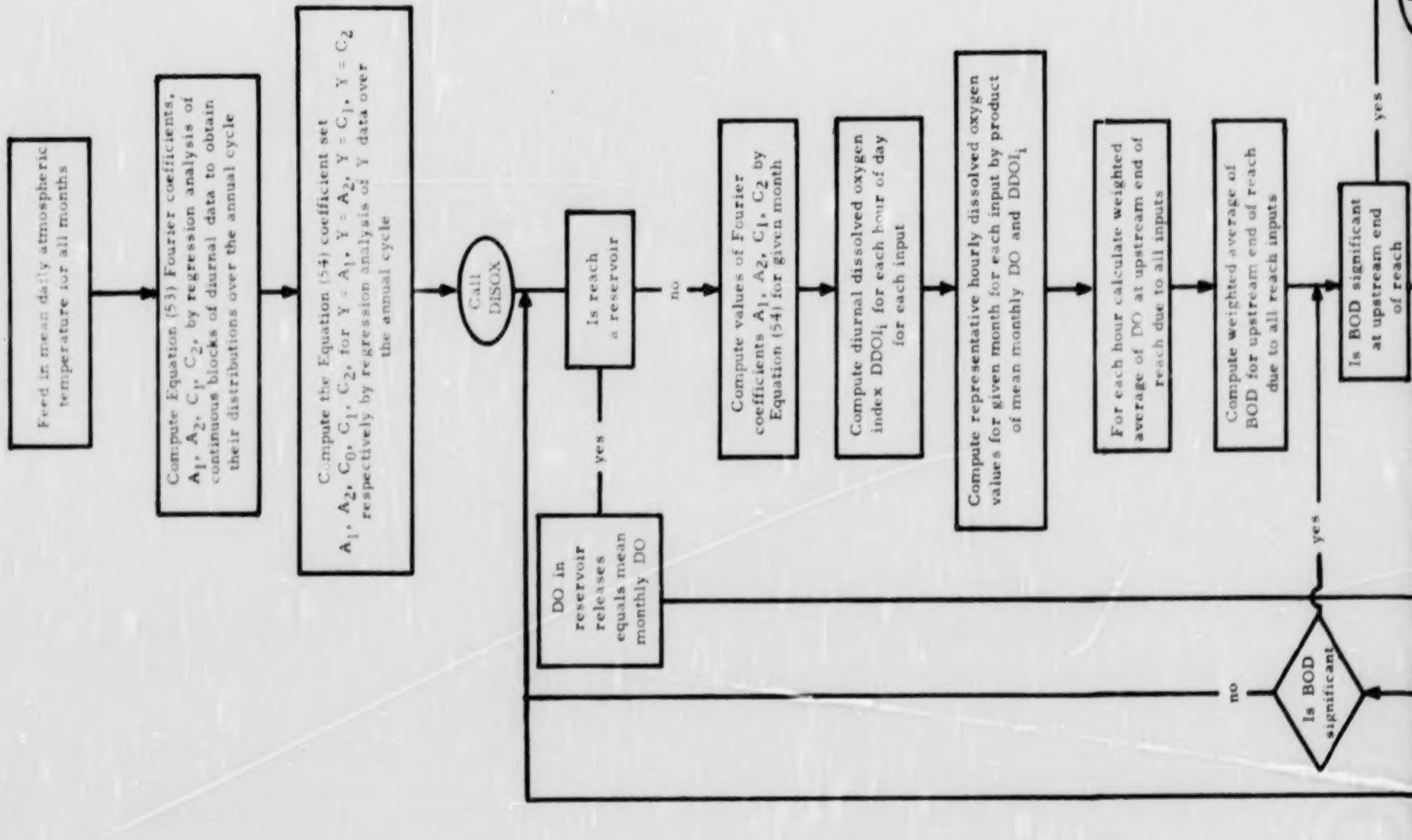
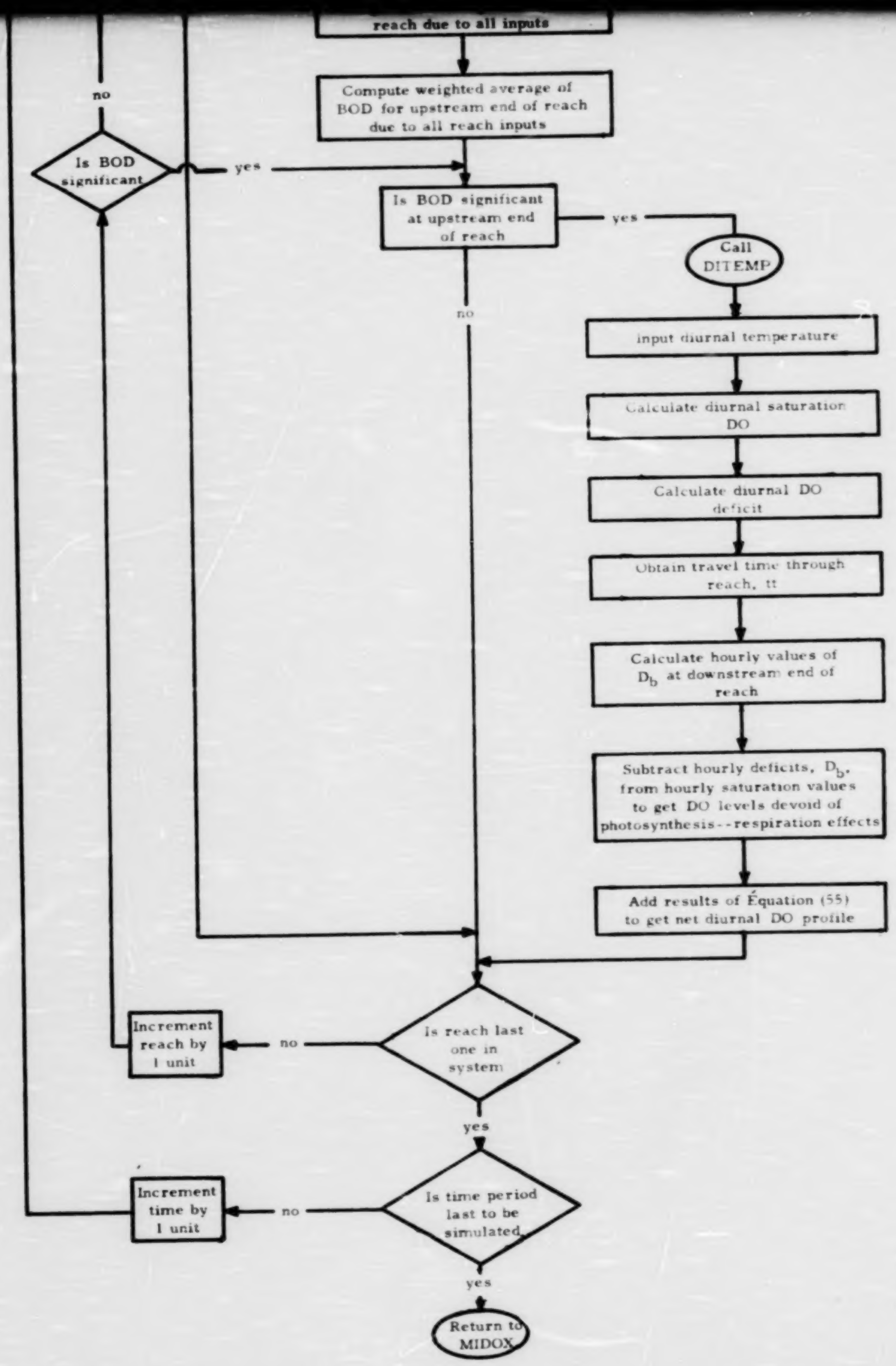

Feed in mean daily atmospheric temperature for all months
Compute Equation (53) Fourier coefficients, A_1, A_2, C_1, C_2, by regression analysis of continuous blocks of diurnal data to obtain their distributions over the annual cycle
Compute the Equation (54) coefficient set A_1, A_2, C_0, C_1, C_2, for $Y = A_1$, $Y = A_2$, $Y = C_1$, $Y = C_2$ respectively by regression analysis of Y data over the annual cycle
Call DISOX
Is reach a reservoir
yes
no
DO in reservoir releases equals mean monthly DO
Compute values of Fourier coefficients A_1, A_2, C_1, C_2 by Equation (54) for given month
Compute diurnal dissolved oxygen index $DDOI_i$ for each hour of day for each input
Compute representative hourly dissolved oxygen values for given month for each input by product of mean monthly DO and $DDOI_i$
For each hour calculate weighted average of DO at upstream end of reach due to all inputs
Compute weighted average of BOD for upstream end of reach due to all reach inputs
Is BOD significant at upstream end of reach
yes
Call
yes
Is BOD significant
no

Figure 34. Generalized flow chart for diurnal D.O. simulation.


reach due to all inputs
Compute weighted average of BOD for upstream end of reach due to all reach inputs
no
Is BOD significant
yes
Is BOD significant at upstream end of reach
yes
no
Call DITEMP
input diurnal temperature
Calculate diurnal saturation DO
Calculate diurnal DO deficit
Obtain travel time through reach, tt
Calculate hourly values of D_b at downstream end of reach
Subtract hourly deficits, D_b, from hourly saturation values to get DO levels devoid of photosynthesis--respiration effects
Add results of Équation (55) to get net diurnal DO profile
Increment reach by 1 unit
no
Is reach last one in system
yes
Increment time by 1 unit
no
Is time period last to be simulated
yes
Return to MIDOX

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CHAPTER VII

EXPLORATION FOR A COLIFORM SUBMODEL

The concentration of coliform organisms is often cited as a parameter of water quality. Though coliform organisms themselves are not pathogenic, their presence in a water supply is generally taken as presumptive evidence of possible contamination by pathogenic bacteria, as some coliform organisms and pathogenic bacteria originate in the intestines of warm blooded animals and exhibit approximately the same die-away characteristics in the aquatic environment. Some coliform bacteria, however, originate in the soil and are carried into the stream by surface runoff and shallow interflow. Virus organisms do not exhibit the same die-away characteristics as coliform bacteria. For these reasons, many authorities argue against the use of the coliform organism as an indicator of pathogenic organisms. However, because coliform count is the parameter in most prevalent use at the present time, and because it is so frequently cited in water quality literature as an index to the bacterial quality of water supplies, coliform count has been studied for possible incorporation into the water quality simulation model.

Literature search

Relatively few works related to the modeling of coliform organisms in natural streams are discussed in the literature. Kunkle and Meiman (1968) have studied the behavior of coliform, fecal coliform, and fecal streptococci in a small high mountain stream flowing through an irrigated meadow pasture. At one of their points of observation, they found analytical technique to be the most significant source of variation in coliform numbers, while at the other location, analytical technique was second only to time-of-day as a source of variation. They made no attempt at establishing a mathematical representation of coliform behavior in the stream.

Frankel (1965), in his study of water quality evaluation, discusses the problem of modeling coliform die-away, finally using Equation 56, as presented by Fair and Geyer (1954). This formulation, also contained in Fair, Geyer, and Okun (1968) is

$$(N_o - y)/N_o = N/N_o = (1 + n \cdot \kappa \cdot t)^{-1/n} \quad \ldots\ldots\ldots\ldots (56)$$

in which

N_o = original number of bacteria in the stream

y = number of bacteria removed during time of flow (t) below the point of maximum bacterial density

N = number of bacteria left in the stream after time of travel (t)

t = time in days

κ = initial rate of die-away for a specific bacterial population in the environment of the receiving stream

n = associated coefficient of nonuniformity or retardation

In this die-away equation, both κ and n are functions of the bacterial population being studied and the environment of the receiving stream into which this population is introduced. These important model parameters must be quantified analytically from samples taken from the stream at points downstream from the point of maximum coliform number. To adequately define the die-away curve, it is necessary to sample over a relatively long flow time, which is the case of the Little Bear River. Its high velocity of flow means that the length of stream sampled should be relatively great.

Because of the location of sources of concentrated bacterial pollution, it was impossible to adequately sample the stream below the points of discharge. The first source of large numbers of coliform is the trout farm which is located about 2.8 miles upstream from Hyrum Reservoir. This distance represents a travel time of approximately 1 to 1.5 hours, depending on the rate of discharge; considerably less than the 10-12 hours suggested by Fair, Geyer, and Okun (1968) as that required to reach maximum coliform density below a sewer outfall.

The second source of concentrated bacterial pollution is the stream into which untreated waste from the town of Wellsville is released. This discharge is located only a few hundred yards upstream from the lower limit of the project study area, with another reservoir pool not far downstream. The inability to establish κ and n for Equation 56 have frustrated attempts to simulate bacterial die-away by this approach. This representation of bacterial die-away appears to be the best that is currently available in the literature.

Figure 35 shows the profile of the logarithm of coliform count, as observed along the length of the main stem of the Little Bear River on 11 September 1968. This profile should not be taken as typical of the pattern of spatial variation; however, as large, apparently random, deviations occur at each individual station. Figure 36 for station 12.5 is a typical annual distribution of the logarithm of the coliform count, showing the stochastic deviation from the mean.

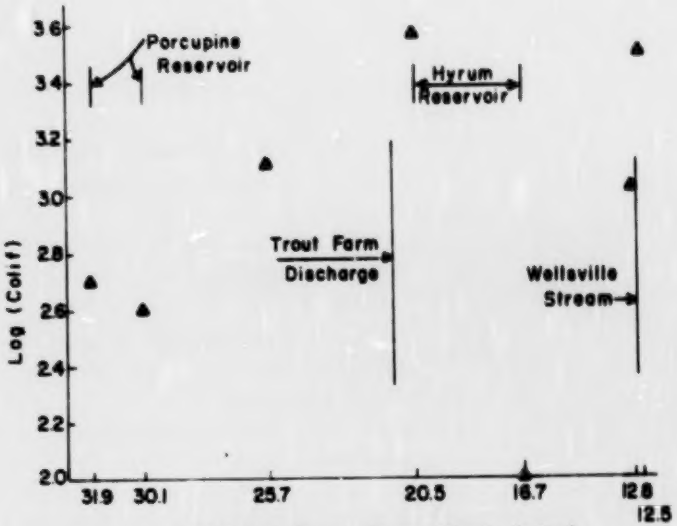

Figure 35. Space profile of log (coliform count) for 11 September 1968.

The density of coliform organisms in a given bacterial sample was assessed by the membrane filter technique. Multiple dilutions of a single replicate sample were processed simultaneously. Bacterial samples were limited to about 10 per weekly sampling period, because of time limitations in the laboratory. This restriction resulted in a rotating schedule for the 16 sampling stations.

Alternatives considered

Post (1968) indicated that the logarithm of coliform density in waste stabilization ponds had been found to be closely related to water temperature. On the strength of this suggestion, an attempt was made to relate the logarithm of coliform density to stream temperature at several locations along the stream. Figure 37 is typical of the results obtained.

In searching for some means to explain the large amount of variation remaining after regressing with water temperature, it was suggested that possibly the random nature of bacterial loading could be the source of at least part of the residual variance. This hypothesis was tested by comparing the residual of the log coliform variation with that of BOD after the influence of temperature had been removed from both. This test was based upon the assumption that both coliform and BOD originate at the same source, i.e. the intestines of warm blooded animals. Figure 38 depicts the result obtained at station S-12.8, which is typical of the stations studied. There is no apparent positive correlation between log of coliform density and BOD. In fact, this particular set of data displays what might be taken as a slight tendency toward negative correlation (larger positive log coliform deviations being associated with negative BOD deviations). These observations tend to eliminate random loading as the major source of residual variation in either coliform or BOD if the assumption of common sources for the two pollutants is valid.

No coliform model, that could be adequately defined from available project data, was discovered in the literature. Analysis of project data failed to produce an equation capable of representing a significant portion of the total variation in coliform count. A random probability model based upon the statistics of available data would suffice as well as any.

Further research in this area would be helpful. Probably the most fruitful approach would be the quantification of relationships governing the die-away rate constant (κ) and coefficient of nonuniformity (n) of Equation 56. Fair, Geyer, and Okun (1968) have suggested that these model parameters are influenced by the bacterial population and the characteristics of the stream into which the bacteria have been injected. In any future investigation involving the coliform count, the data of Kunkel and Meiman (1968) would suggest that replicate laboratory tests be conducted for each dilution to facilitate the assessment of the variance component attributable to analytical technique.

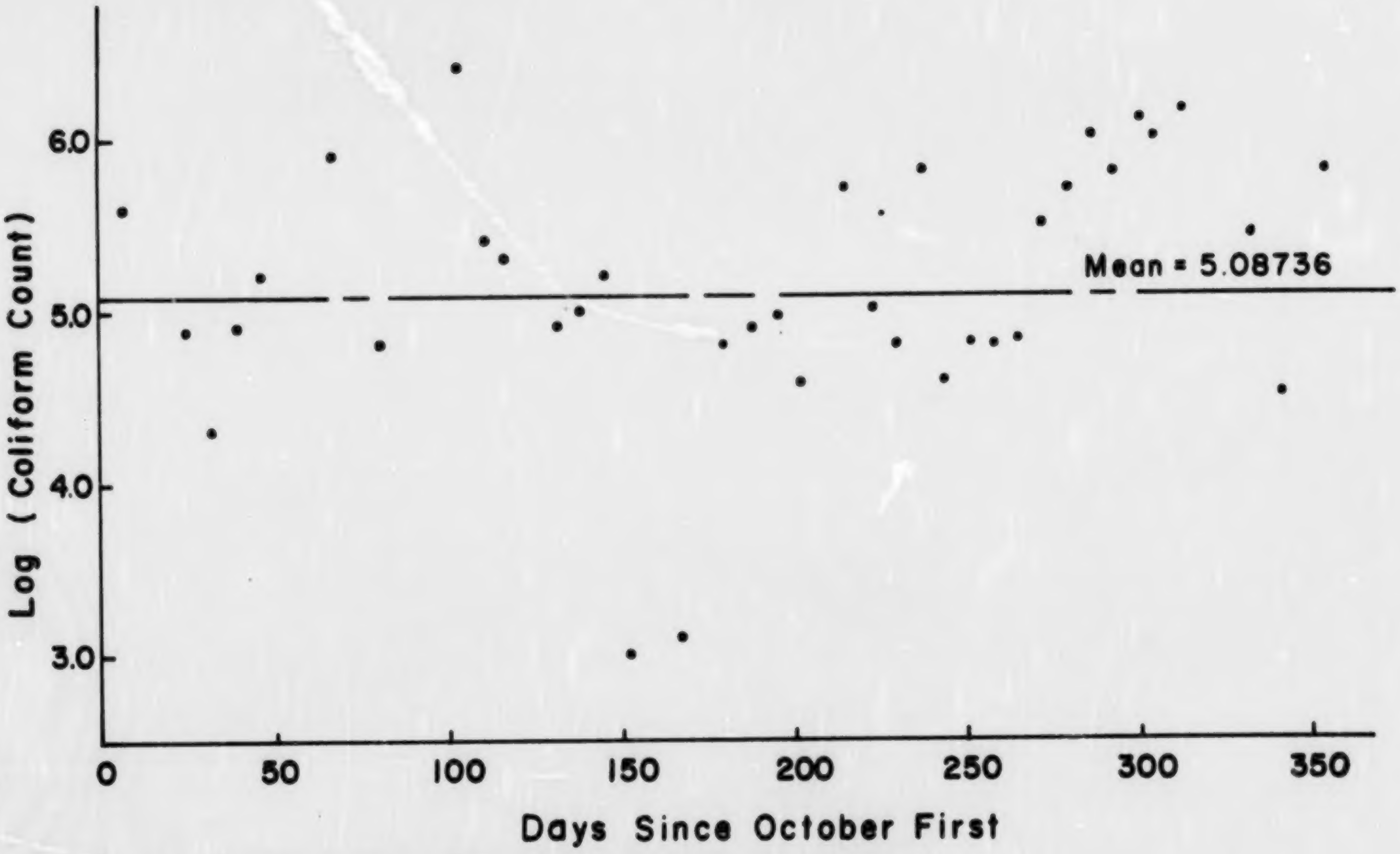

Figure 36. Annual variation in log (coliform count) at station S-12.5 for 1966-67.

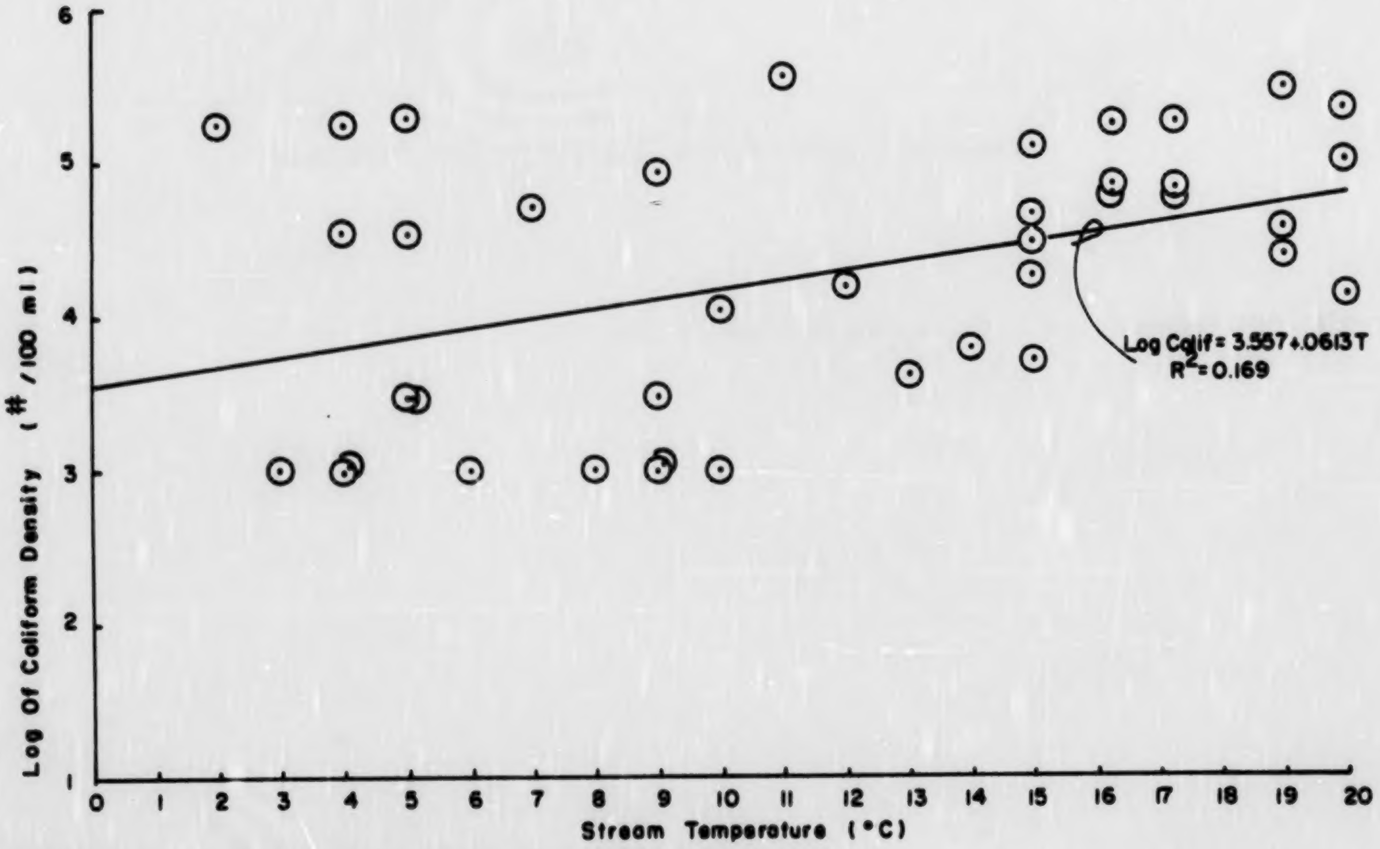

Figure 37. Log (coliform count) vs. stream temperature (station S-12.8).

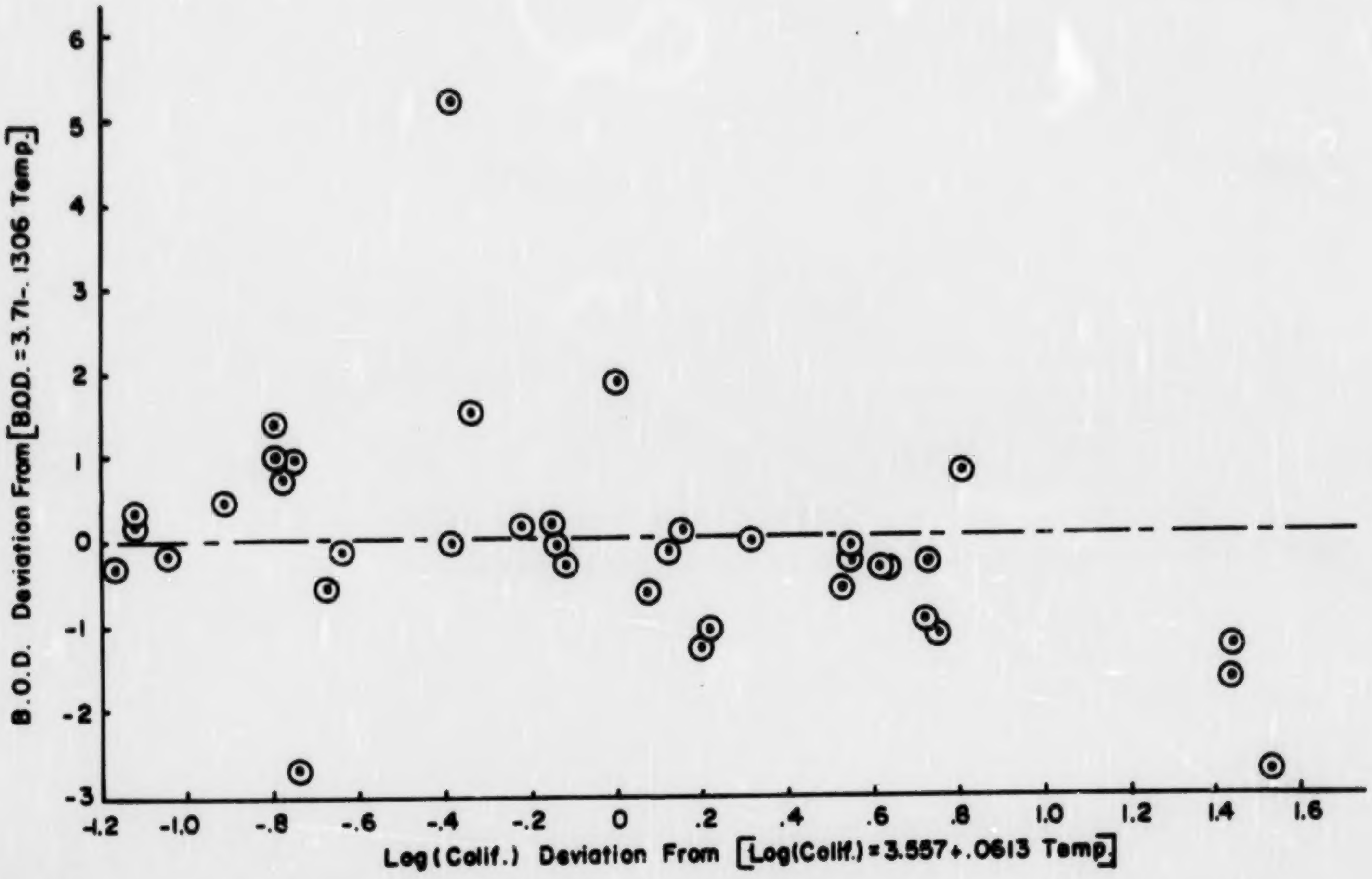

Figure 38. BOD deviation vs. log (coliform) deviation (station S-12.8).

CHAPTER VIII

SIMULATION RESULTS—LITTLE BEAR RIVER

Establishing a simulation model can be summarized as two steps: (1) establishment of model constants and coefficients, and (2) verification of the resulting model. This was done using 1966-1967 and 1967-68 data for the first and second steps respectively. The following is a discussion of results. The submodels and procedures outlined in the previous chapter were used to derive all results presented herein.

System delineation

The Little Bear River system, shown in Figure 59, is represented schematically in Figure 39. This sketch shows the breakdown of the stream system into major tributary branches and reaches, as well as locations of reservoirs, waste discharge points, and control points. Node points between reaches fall at hydrologically significant break points in the system. Reach eight on the main stem, for instance, extends from Porcupine Reservoir discharge on the upstream end to the Paradise Canal diversion at the downstream end of the reach. Locations and designations of system node points are tabulated in Table 20.

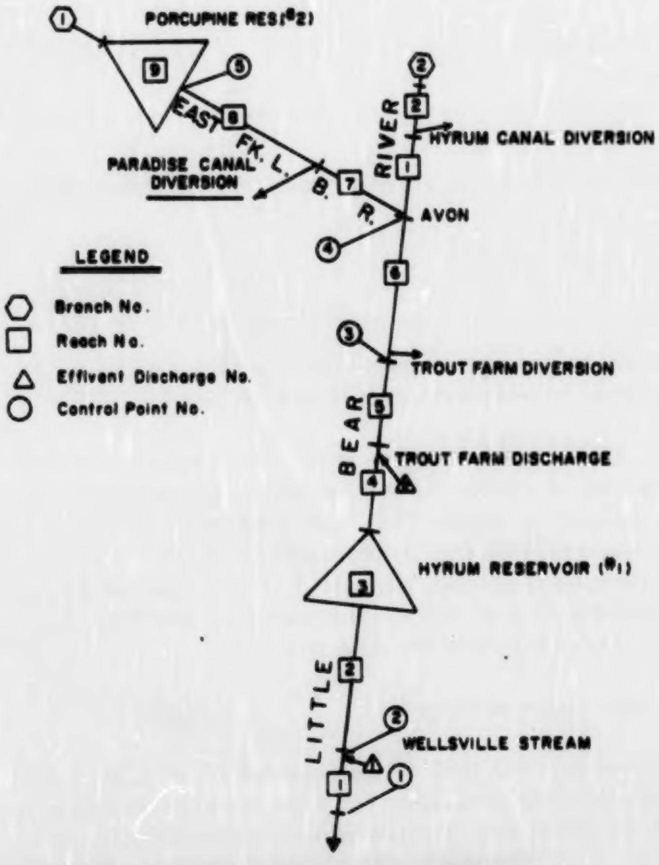

Figure 39. Little Bear River system schematic.

Establishing model coefficients

Submodel coefficients have been determined, where possible, by least squares analysis of 1966-67 data using equations selected and described in the previous chapter. Where data required for evaluation of constants and coefficients were not available, estimated values were used in the simulation. These estimates were revised, where necessary, to achieve correspondence between simulated water quality and monthly averages of observed data. Procedures followed and results obtained are outlined below for each submodel.

Electrical conductance

Electrical conductance was found to be quite sensitive to changes in the ratios of groundwater to surface water inflows. After the first simulation run, the groundwater coefficients in the hydrologic submodel were altered to change the proportions of these unmeasured inflows. Estimates of irrigation return flow conductivity were also revised downward to achieve better correspondence between observed and simulated conductivities. Correspondence graphs from the last 1966-67 run are shown in Figure 40 for four typical observation stations along the Little bBear River main stem.

Sample simulation profiles are shown in Figure 41 for the months of January and July, 1968. A full year of profiles is shown in Appendix F. Average values of field data, for corresponding months, are also shown for comparison. The gradual build-up in electrical conductance in the downstream direction is characteristic of the field data. Drops at stations 30.1 and 16.7 are due to carryover of low-conductance spring runoff in Porcupine and Hyrum Reservoirs, respectively.

Table 20. Little Bear River reach description.

Branch No.	Reach No.	From	To	Location[a]	Length (mi.)
1	1	Wellsville	telemetry site	1.125	0.3
1	2	Hyrum dam	Wellsville	1.128	3.9
1	3	–Hyrum Reservoir		1.167	1.8
1	4	trout farm discharge	Hyrum res.	1.185	2.8
1	5	trout farm diversion	trout farm discharge	1.213	1.1
1	6	South Fork	trout farm diversion	1.224	3.2
1	7	Paradise canal diversion	South Fork	1.257	1.3
1	8	Porcupine dam	Paradise canal diversion	1.270	3.1
1	9	–Porcupine Reservoir–		1.301	1.8
2	1	Hyrum canal diversion	Avon	2.000	1.0
2	2	Davenport Creek	Hyrum canal diversion	2.010	0.3

[a] The location designation is "b.xxx" where b is the branch number and xxx is the distance from the mouth of the branch, in tenths of a mile (2.010 = one mile above the mouth of branch two).

Monthly water temperature

After the initial adjustment of hydrologic inputs, using conductance data as a guide, no further changes were made in the system hydrology. The simulation submodel for water temperature was adjusted by changing the "equilibrium" water temperature model coefficients and the heat exchange coefficient.

Typical correspondence graphs from the final model development run are shown in Figure 42. The maximum deviation from stream temperatures, measured at eight observation points along the stream is about 4°C at station S-12.8. Departures of this magnitude occur during May and June; simulated temperatures being high in May and low in June at this particular location. These larger deviations at the lower sampling points are probably attributable to the approximate nature of the simulation of release water temperatures at Hyrum Reservoir.

Comparisons of simulated and observed stream temperature profiles for the months of January and July are depicted in Figure 43. It is interesting to note that in January the influence of groundwater inputs on stream temperature is positive, while in July it is negative. Sharp temperature drops through the thermally stratified reservoirs are prominent in the July profile.

Monthly dissolved oxygen

For the low BOD levels observed in the Little Bear River, the D.O. simulation was more sensitive to changes in D.O. inputs than to changes in oxygen sag model parameters. Had BOD levels been higher, it is quite likely that

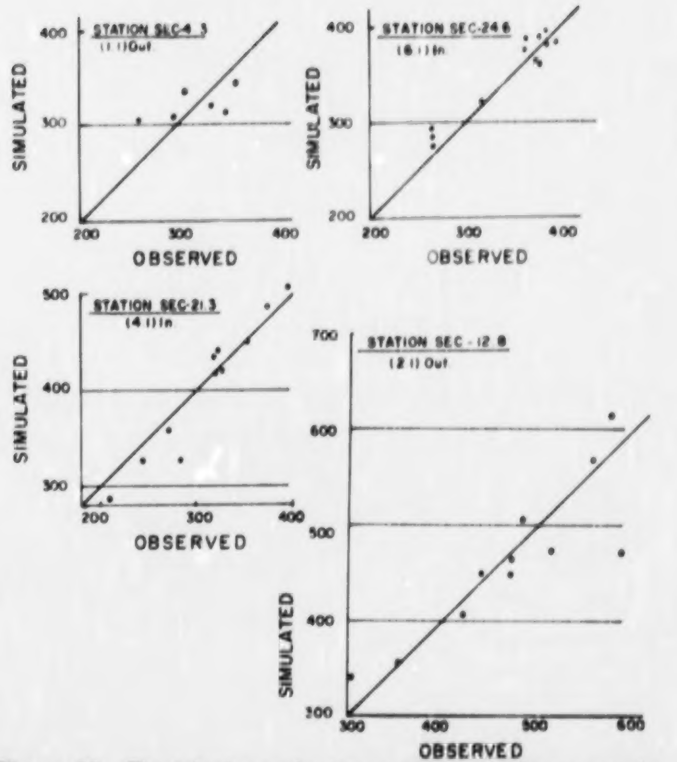

Figure 40. Electrical conductance correspondence graphs for stations SEC-4.3, S-24.6, S-21.3 and S-12.8 from the final model development run (1966-67 data).

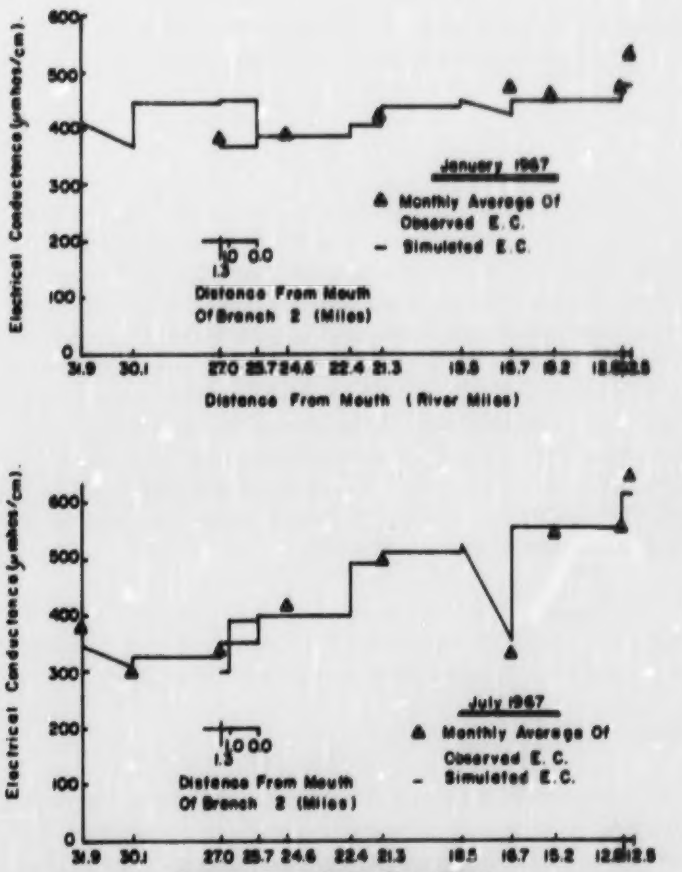

Figure 41. Comparison of observed and simulated electrical conductance profiles for January and July, 1967.

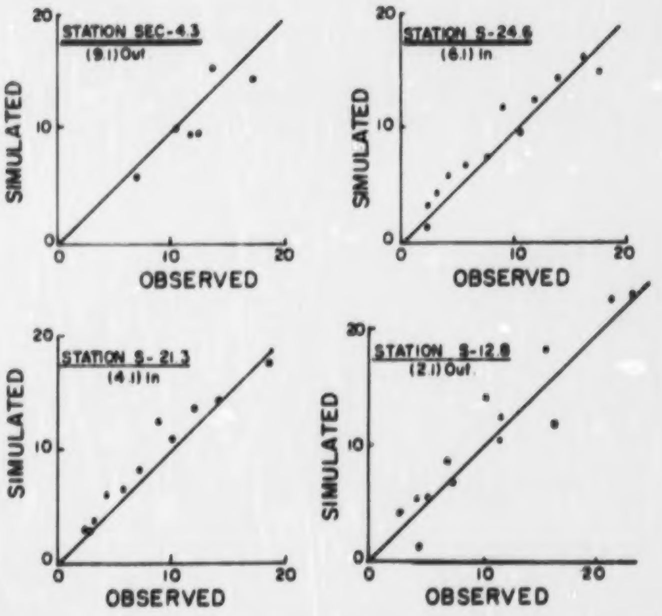

Figure 42. Water temperature correspondence graphs for stations SEC-4.3, S-24.6, S-21.3 and S-12.8 from the final model development run (1966-67 data).

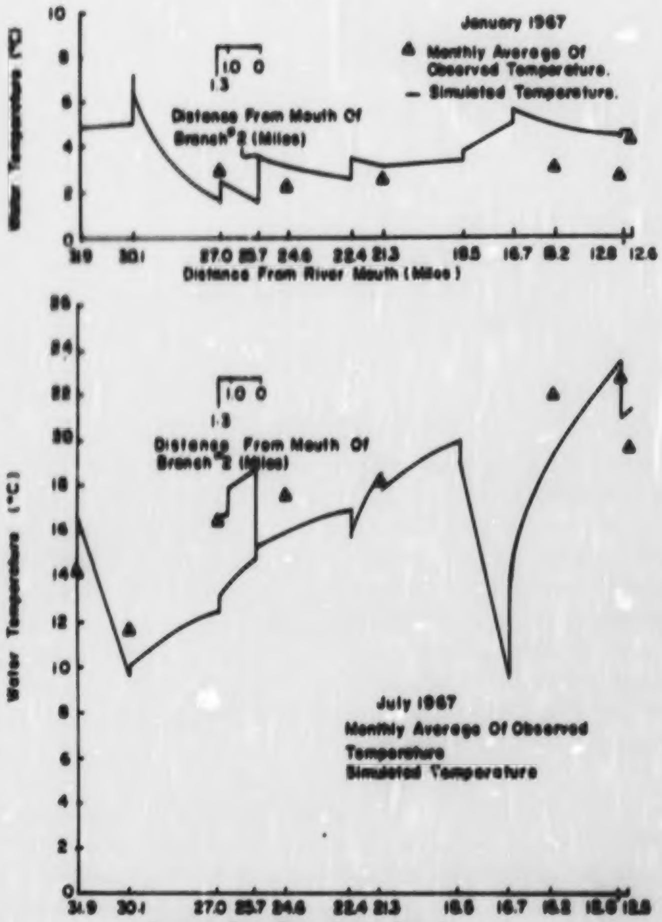

Figure 43. Comparison of observed and simulated water temperature profiles for January and July, 1967.

adjustment of the oxygen sag model parameters would have significantly improved the model results.

Dissolved oxygen correspondence graphs are shown in Figure 44 for 1966-67 data. With the exception of station S-12.8, simulated D.O. concentrations were generally within 1 mg/l of observed concentrations. Departures on the order of 2 mg/l may be noted at S-12.8. These greater deviations occurred during the months of October, November, and January. Observed data show a high degree of supersaturation during these three months. As will be shown later (Figure 54) these heavy supersaturations were not observed in 1967-68 data. The departures at station S-12.8 in 1966-67 are unexplained at this point.

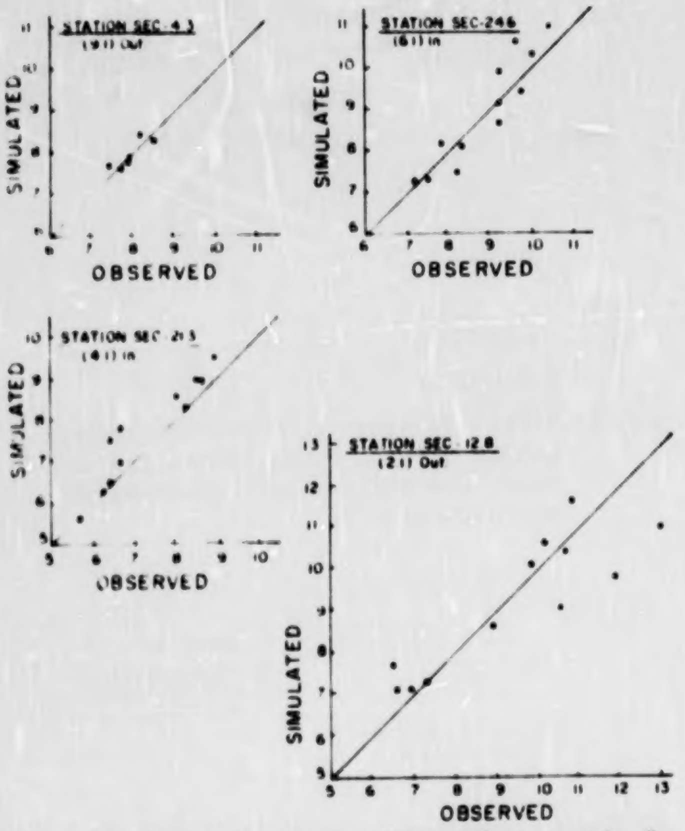

Figure 44. Dissolved oxygen correspondence graphs for stations SEC-4.3, S-24.6, S-21.3 and S-12.8 from the final model development run (1966-67 data).

The simulated D.O. profiles for January and July exhibit discontinuities at node points between branches (Figure 45). These discontinuities result from the assumption that oxygen deficient groundwater inflows are concentrated at the upstream end of the reach. Combining this concentrated low D.O. inflow with the other inflows at the upstream end of the reach results in a noticeable depression of the D.O. profile at this point. This is particularly true where groundwater inflow makes up a significant portion of the total input to the reach, as it does in many reaches of this system during periods of low streamflow. The downward step in D.O. at station 21.3 results from the release of large quantities of oxygen deficient waters from the ponds and channels of the commercial fish farm. The relatively large deviations at station 15.2 are apparently caused by a small quiescent pool immediately upstream from the field observation point. During low flow periods, velocity is low through this pool and photosynthetic organisms abound.

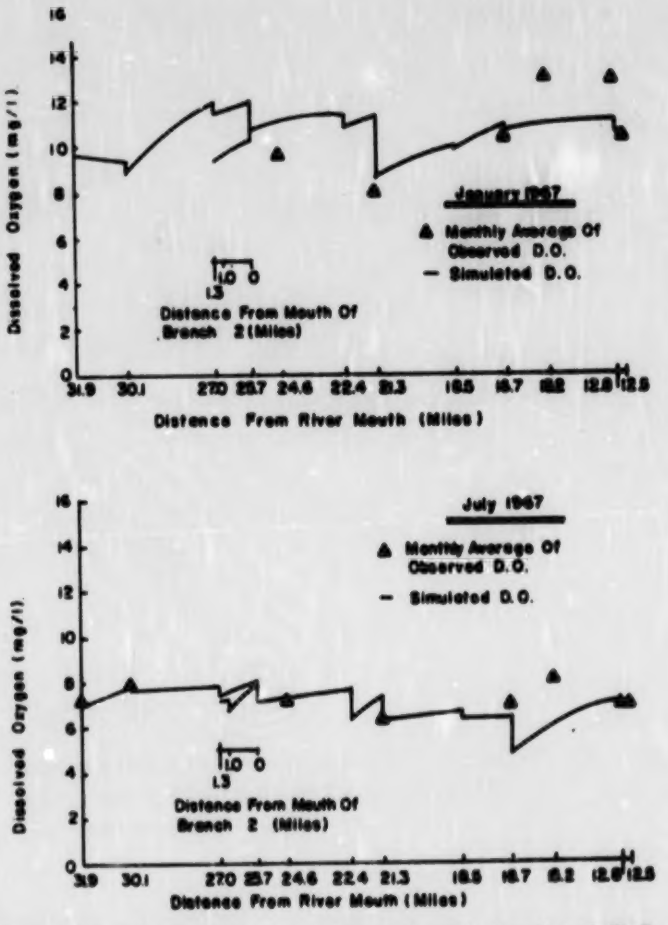

Figure 45. Comparison of observed and simulated D.O. profiles for January and July, 1967.

A full year of simulated D.O. profiles for 1967-68 years are shown in Appendix F. These profiles are based upon coefficients established using 1966-67 data.

Diurnal water temperature

It has been assumed that the hourly distribution of the ratio of observed temperature to mean daily temperature should be approximately the same at any point in the stream system as was recorded at Wellsville. In the case of the Little Bear River, where there are no concentrated sources of thermal pollution, this assumption is justifiable. Some departure from this relationship should be expected, however, especially immediately downstream from surface impoundments.

The variation pattern for the simulated diurnal temperature index, at control points not immediately downstream from reservoirs, was adjusted to conform to the pattern calculated from continuous monitoring data at S 12.5. The simulated diurnal temperature index was found to be quite sensitive to the heat exchange coefficient and the magnitude of "equilibrium" temperature variations. Trial and error adjustment of these factors was the principal means of adjusting the simulated temperature index distribution. In Figure 46 the simulated and measured diurnal temperature index patterns for station S-12.8 are shown for the month of May 1967.

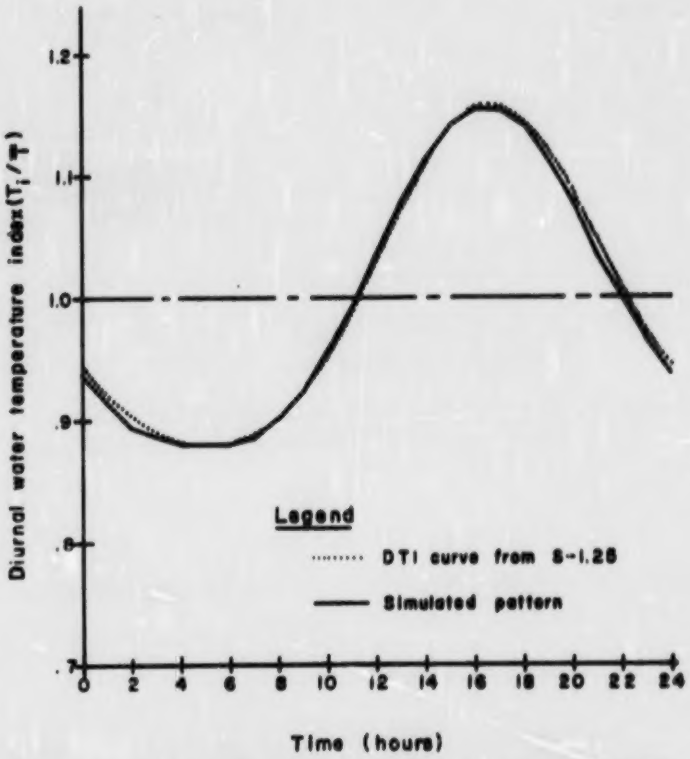

Figure 46. May 1967 diurnal water temperature index pattern for station S-12.8.

Diurnal dissolved oxygen

As with diurnal modeling of water temperature, the basis for adjusting the simulated dissolved oxygen index distribution was the assumption that this distribution should approximate that calculated from continuous data from the Wellsville monitoring station. Differing environmental conditions, such as prevailing direction of flow, bank vegetation and topographic relief, result in spatial variations in light intensity patterns through the day. These influences may be expected to impart deviations from the relationship assumed.

The simulated D.O. distributions were found to be sensitive to changes in the diurnal temperature distribution, primarily because of the dependent relationship between oxygen saturation concentration and water temperature. After attaining a satisfactory distribution of water temperature, D.O. distributions were adjusted by altering the "productivity coefficient" on a month-by-month basis for each reach. This "productivity coefficient" is the scaling factor in Equation 55, enabling the diurnal dissolved oxygen index curve to be used to simulate photosynthetic activity within a stream reach.

The diurnal D.O. index pattern for station S-12.8 is shown for the month of May 1967, in Figure 47, along with the index curve derived from continuously monitored D.O. data. A consistent tendency toward somewhat later peaks in the simulated diurnal D.O. distribution pattern was observed.

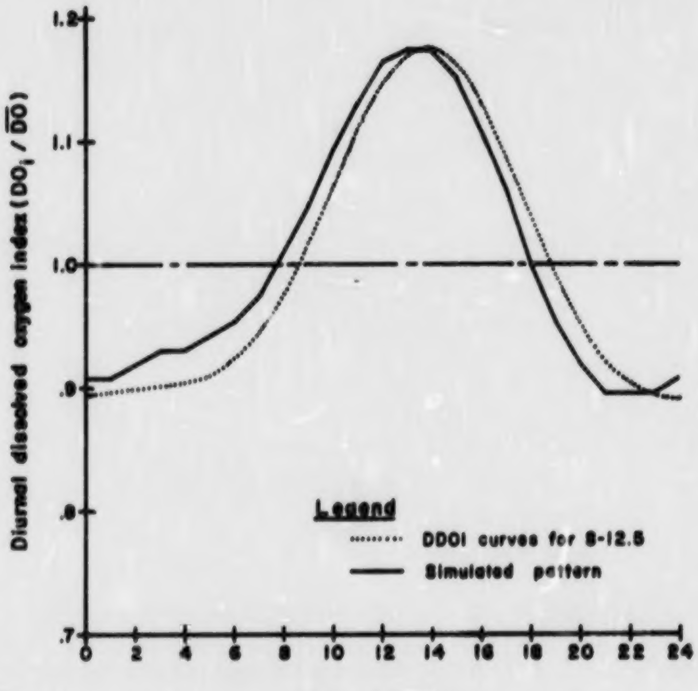

Figure 47. May 1967 diurnal dissolved oxygen index pattern for station S-12.8.

Verification of model constants and coefficients

For verification, the completed water quality model was applied to hydrologic data taken during the 1967-68 water year and compared to 1967-68 water quality data. The results from each submodel will be discussed briefly.

Electrical conductance

Hydrologic coefficients and inputs for the hydrologic simulation submodel were adjusted using 1966-67 data. No further changes were made in the hydrologic submodel. The correspondence graphs for six stations (Figure 48) show roughly the same degree of scatter for the 1967-68 run as were observed in Figure 40 from the last 1966-67 run. The inadvertent omission of temperature compensiation on a conductivity meter for the period June 1966 through February 1968, undoubtedly contributes somewhat to the deviations for exact correspondence observed in Figure 48.

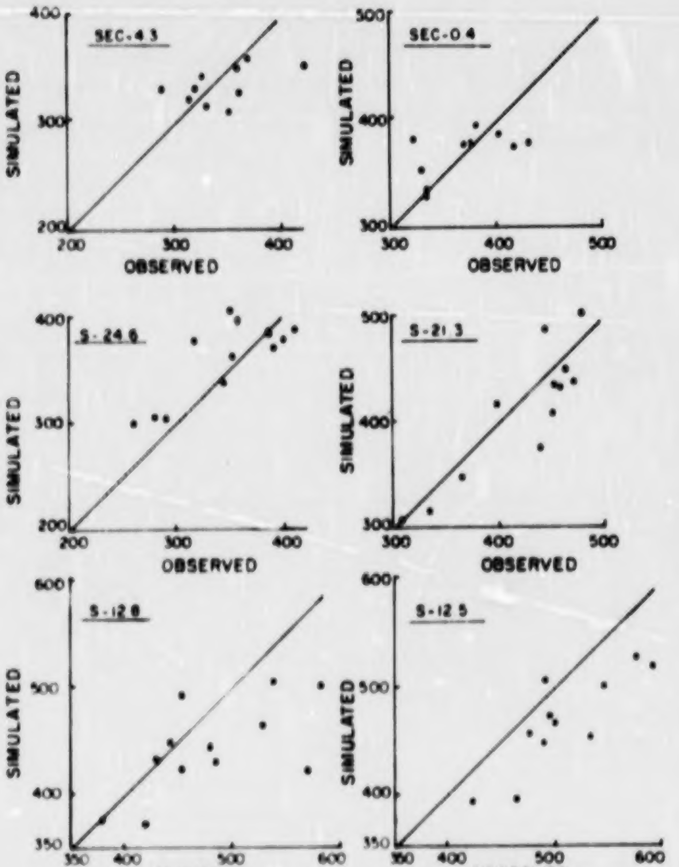

Figure 48. Electrical conductance correspondence graphs from the model verification run (1967-68 data).

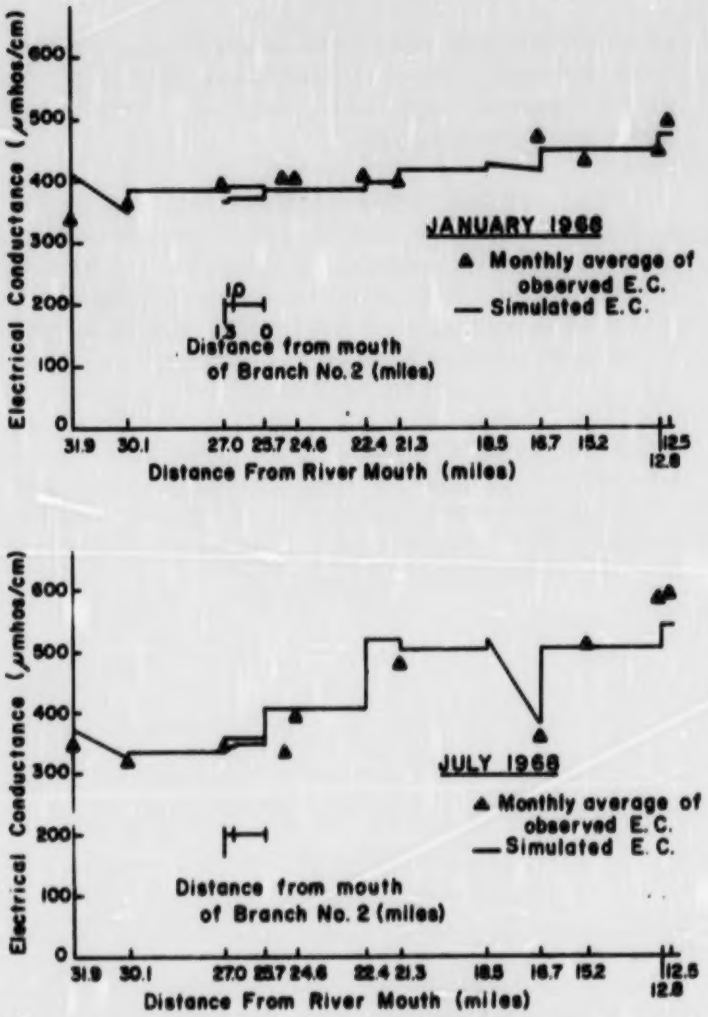

Figure 49. Comparison of observed and simulated electrical conductance profiles for January and July 1968.

Conductivity profiles for the months of January and July, 1968, are shown in Figure 49 as samples of the profiles resulting from the model verification run. A complete set of plotted conductivity profiles is included in Figure F-1 of Appendix F. Comparison of simulated and observed annual distributions of mean monthly conductivity is featured in Figure 50 for quality sampling stations S-12.8 and SEC-0.4. The good correspondence between observed and simulated electrical conductance values is readily apparent in all of these figures.

Monthly water temperature

The simulated 1967-68 stream temperatures correspond well with observed temperatures as Figure 51 shows. This correspondence is similar to that depicted in Figure 42 for the last 1966-67 run. Sample stream temperature profiles for the months of January and July, 1968, are illustrated in Figure 52. Figure F-2, Appendix F, provides a complete set of plotted stream temperature profiles for each month of the simulation year. Observed and simulated annual distributions of mean monthly stream temperature are compared in Figure 53.

Monthly dissolved oxygen

Relatively good correspondence was found between observed and simulated dissolved oxygen concentrations as shown in Figure 54. This agreement, however, should not be taken as conclusive evidence that the oxygen sag model parameters used in the simulation are the most appropriate for the stream, because of the low level of BOD found throughout most of the stream system. January and July simulated D.O. profiles also correspond well with observed data as Figure 55 shows. Figure F-3, Appendix F, contains simulated D.O. profiles for every month of the year. Annual distributions of simulated and observed dissolved oxygen are shown for observation stations S-12.8 and SEC-0.4 are shown in Figure 56.

Diurnal water temperature

Figure 57 compares the computed May 1968 diurnal water temperature index pattern for station S-12.8 with that derived from continuous monitoring data for station S-12.5. The correspondence is excellent as well it should be as the simulation coefficients were derived for May data of the previous year.

Diurnal dissolved oxygen

The simulated diurnal D.O. index pattern for the month of May 1968 at station S-12.8 is compared graphically in Figure 58 with the diurnal D.O. index curve derived by analysis of continuous monitoring data from the Wellsville monitoring station. Again the correspondence is good.

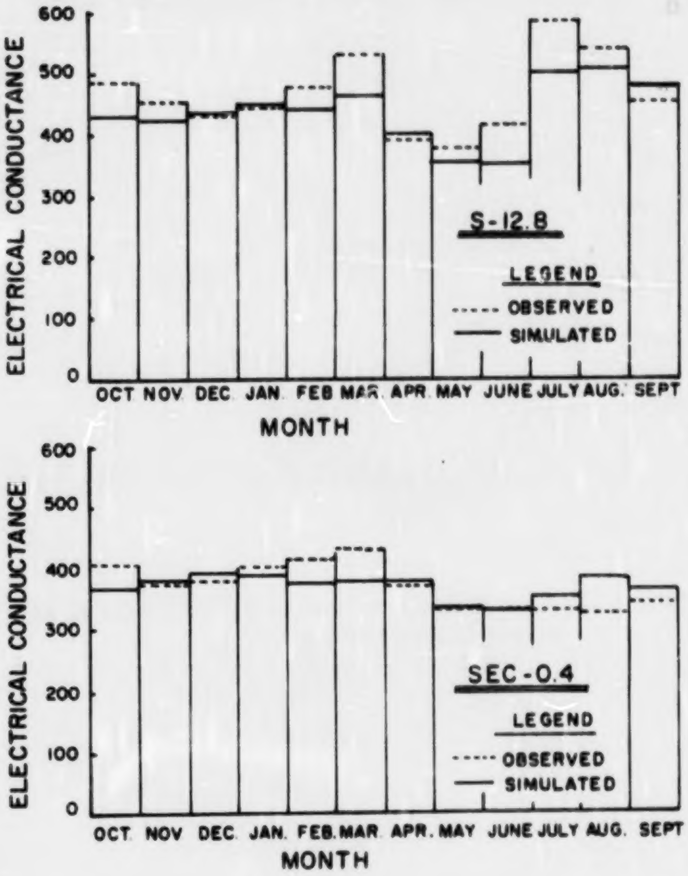

Figure 50. Annual electrical conductance distribution of stations S-12.8 and SEC-1.4.

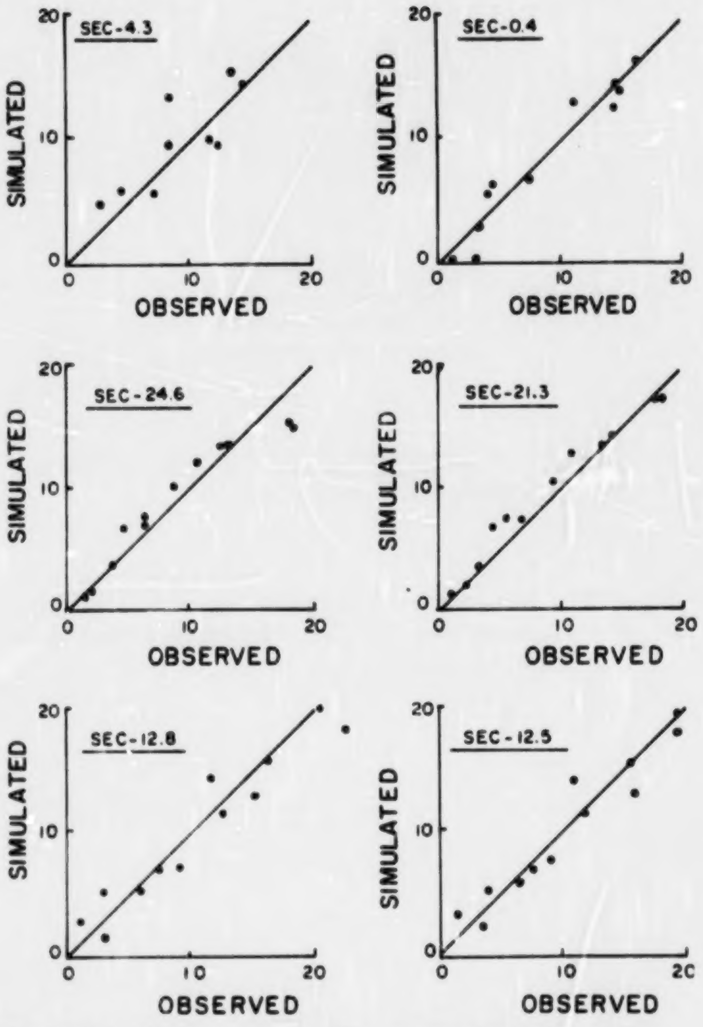

Figure 51. Water temperature correspondence graphs from the model verification run (1967-68 data).

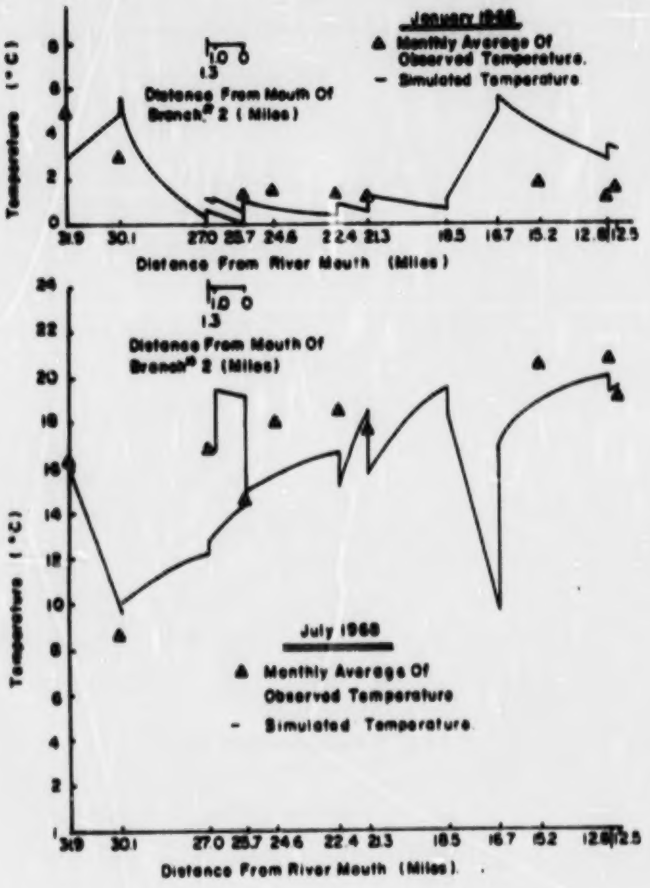

Figure 52. Comparison of observed and simulated water temperature profiles for January and July, 1968.

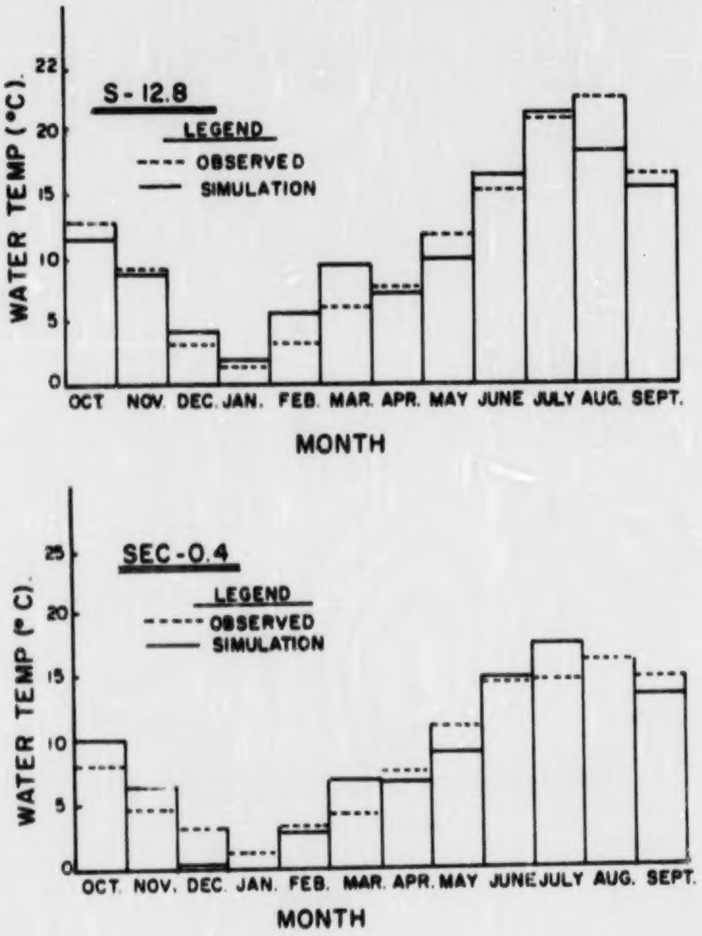

Figure 53. Annual water temperature distribution at stations S-12.8 and SEC-0.4.

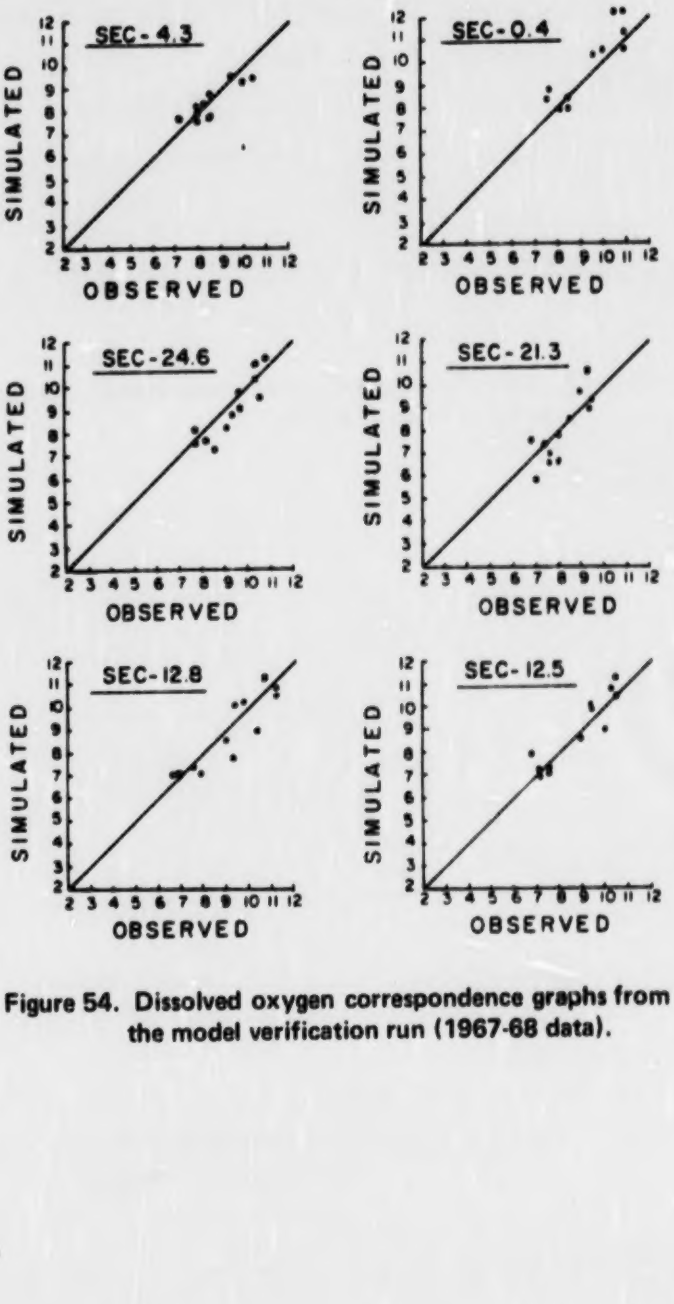

Figure 54. Dissolved oxygen correspondence graphs from the model verification run (1967-68 data).

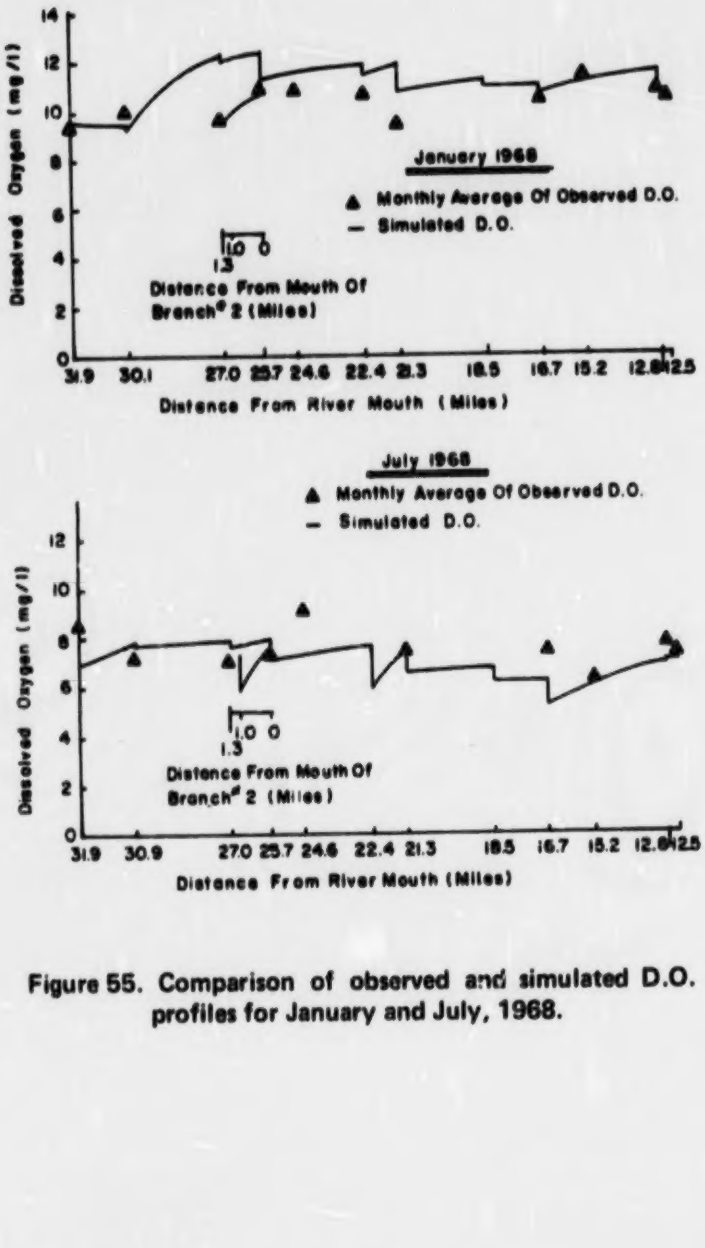

Figure 55. Comparison of observed and simulated D.O. profiles for January and July, 1968.

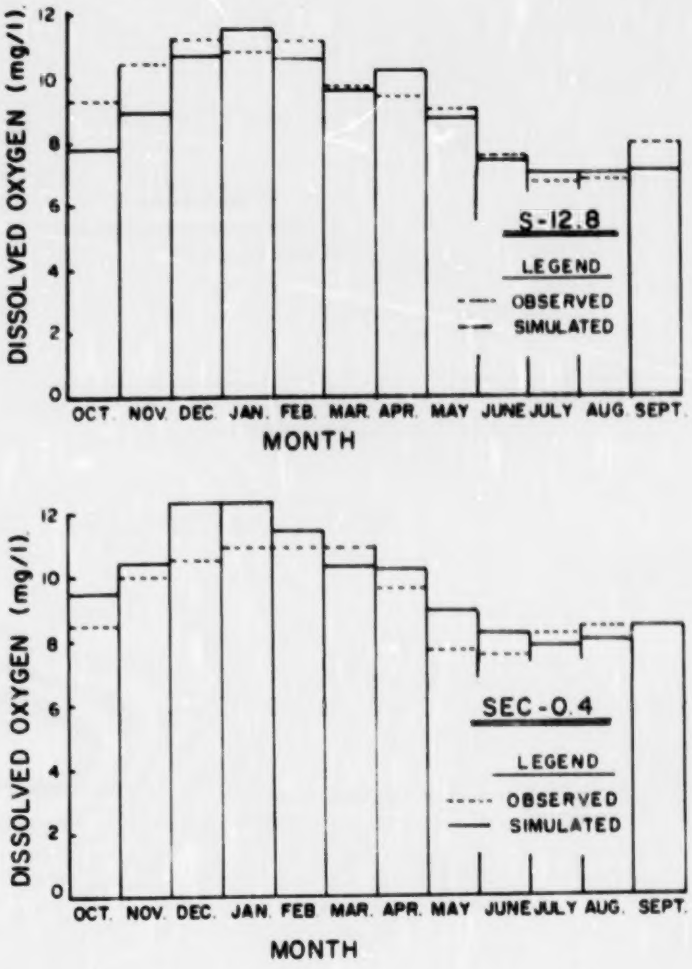

Figure 56. Annual dissolved oxygen distribution at stations S-12.8 and SEC-0.4.

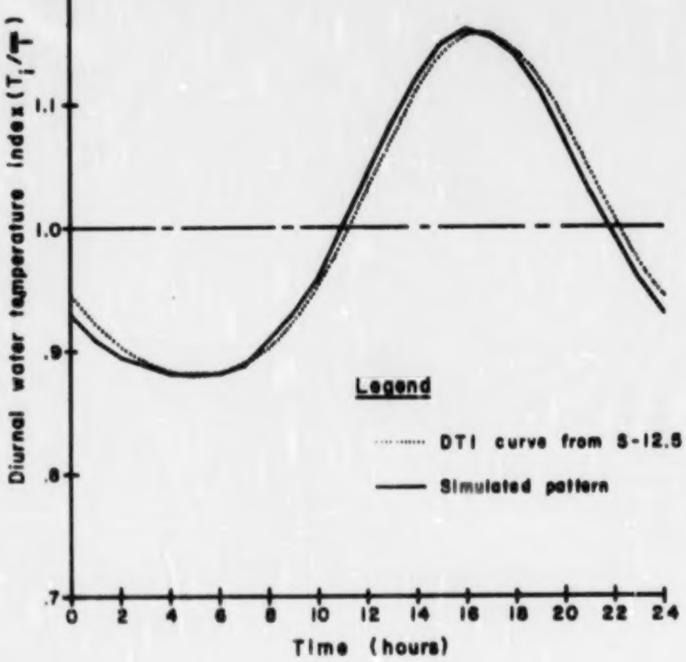

Figure 57. May 1968 diurnal water temperature index pattern for station S-12.8.

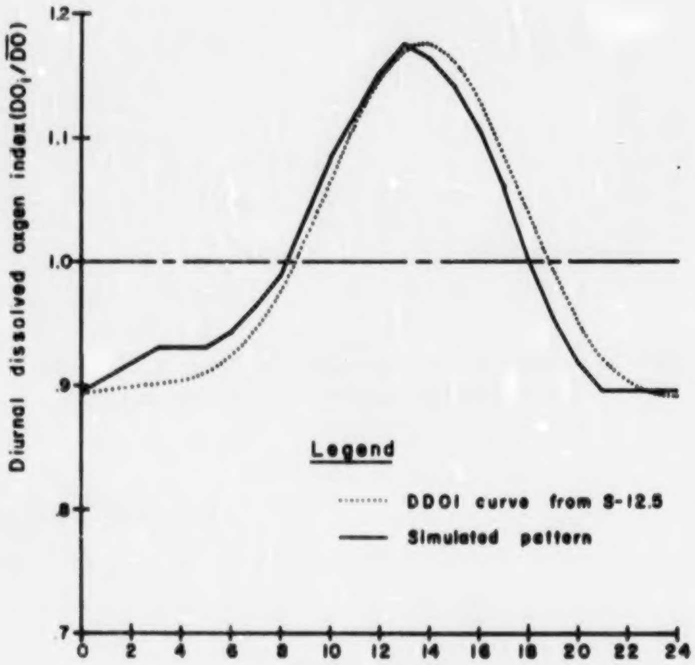

Figure 58. May 1968 diurnal dissolved oxygen index pattern for station S-12.8.

CHAPTER IX

SUMMARY AND CONCLUSIONS

The development of a river basin simulation model has been demonstrated. This model is comprised of dissolved oxygen, temperature, specific electrical conductance, and basin hydrology submodels.

While it is anticipated that the model can be useful as it stands, without modification, its significance may be less than intended if focus is strictly on the model *per se.* River basin modeling implies a diversity of needs, interests and mix of variables, which are unique to a given system. Thus for another situation the time and space resolution needed may be different, data procurement may be more or less facile, and parameters of interest may or may not coincide with this model.

It is the *demonstration* of model development that contains both the explicit and implicit guides and the necessary broadness and generality useful for the divergent applications and conditions in river basin modeling. Also the *concept* of river basin modeling is formalized and advanced a step further by the very fact that the demonstration for a real system has been accomplished, as well as by specific techniques or facts advanced.

The system model is the device for studying practical questions involving some measure of efficiency—whether this be pollution minimization by treatment and flow regulation, maximizing water use with the quality constraint, maximizing economic efficiency, or in developing more comprehensive water laws. These questions can be ascertained by simulation of altered conditions, sensitivity analysis, or some optimization technique.

In a tangible sense, how to conceptualize and synthesize a river basin hydro-quality model has been shown. How to design and handle simulation of the significant factors and processes in a pragmatic manner, how to best utilize data to obtain coefficients, and how to synthesize individual events and processes into a system model—are questions treated implicitly in demonstrating the model development. And finally, of course, an operational model—useful at least for the conditions—has been developed.

Some of the specific conclusions emerging from this study are enumerated as follows:

1. The results of this study demonstrate a method for synthesizing a water quality simulation model for a hydrologic system.
2. This model may be expanded or diminished in detail, with respect to reaches, branches, and reservoirs, as conditions and needs warrant.
3. The particular submodels developed for this work may or may not be adequate in capabilities for a given task. It was not intended that these submodels be considered as comprehensive; rather the method of approach consisting of: (a) process studies, (b) model synthesis, and (c) validation and verification, should be considered as the pattern for revision or development of new submodels.
4. Pragmatism in model building is a paramount consideration; this consists of faithful simulation in the time and space scale needed while using input data which are feasible to obtain. The complexity of the model would not normally be a problem as long as the mathematics and operations are programmed on a computer.
5. The data network for model development and validation must be *economically* developed in both time and space. The results of the present effort provide implicit guidance. The selection of significant node points is probably the most important aspect of space selection. In time, significant annual and diurnal trends must be established for all important inputs—diffuse and discrete. Stochastic inputs should at least be recognized as such, and if possible a probability density function should be developed.
6. The results of the current effort permits identification of time and space *trends* in the magnitude of a given parameter. Such trends are unique to the system under study. Data used to validate submodels should be trend oriented; this will allow selective and economical procurement of data.
7. The results demonstrate that simulation of stream water quality is feasible when tied to a hydrologic submodel.
8. The transferability of the model to other river systems can be done after proper validation using data from the other system.

9. The model will yield results which can be quantitatively useful in:

(a) apportionment of the assimilative capacity of a stream in such a manner as to meet specified stream standards at critical points along the stream and at critical annual or diurnal time periods

(b) assessment of the system effects of new reservoirs and diversions

(c) assessment of effects due to modifying the operation of reservoirs

10. The model can yield levels of inputs to production functions for an economic model.

11. The literature provides much guidance in developing submodels, but innovation is still required to allow for deviations and to make the submodels work.

12. Appendix H was developed as a supplement. This appendix shows how large masses of data can be scanned in order to discern significant relationships between measured quality and quantity variables.

13. The model will allow comprehensive assessment of any perturbations of the hydrologic or water quality subsystems. For example an imposed BOD or temperature load can be routed downstream with the diurnal behavior of the stream superposed.

14. Temperature and dissolved oxygen exhibit significant diurnal and annual cyclic behavior; this behavior should be incorportated in any comprehensive river basin model.

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APPENDIX A

DESCRIPTION OF THE PROTOTYPE SYSTEM

In order that data be available for testing alternative submodels (or developing submodels, where those available were not deemed adequate) and verifying the finished model, it was necessary that a prototype hydrologic system be selected and monitored. The Little Bear River basin at the southern extremity of Cache Valley in northern Utah was selected for this purpose. On the following pages a general description of the basin, its climate, culture, and pollution problems, is outlined. Table A-1, in particular, summarizes some of the important features relating to the use of the water resources of the system.

Location and geography

The Little Bear River basin above Wellsville, Utah, shown in Figure A-1, is a typical intermountain valley encompassing some 245 square miles total drainage area and lying between 41°-39' and 41°-23' north latitude and between 111°-45' and 112°-00' west longitude. With the exception of the portion of the north boundary crossing the valley floor, the entire boundary of the study area coincides with the natural hydrologic divides surrounding the basin. The north boundary across the valley floor runs east and west at a point just north of Wellsville and Hyrum, Utah.

The basin topography may best be described as rugged to rolling in form. Elevations range from 9445 feet on James Peak at the extreme southern end of the basin to approximately 4500 feet at Wellsville on the northern edge.

The portion of the basin herein called the valley floor is generally that lying below the 5000 foot contour, with that above this elevation being referred to as the watershed.

Geology

Cache Valley, Utah and Idaho, of which the valley floor area of the Little Bear River forms the southernmost extremity, is an inferred garben or down-faulted block surrounded by rugged upstanding mountains (Williams, 1958).

The bedrock of the Little Bear River watershed consists of Precambrian, Paleozoic, and Tertiary rocks of limestone, dolomite, shale, sandstone, conglomerate, quartzite, phyllite, and volcanic tuff (Williams, 1958).

The valley fill, on the other hand, is composed of unconsolidated Quaternary classic sediments derived from the surrounding watershed area, precipitates accumulated under old Lake Bonneville and pre-Lake Bonneville deposits in the form of alluvial fan gravels, concealed deposits and landslide deposits (Williams, 1958). This valley fill forms the major groundwater aquifer of the basin, having recharge areas at the canyon mouths and along the periphery of the valley. At points in the valley floor alternating layers of coarse and fine material form confined aquifers which exhibit artesian pressures. Figure A-2 shows a representative east-west section across the valley. The high angle faults along the face of the mountains on both sides of the valley floor and deep valley fill of unconsolidated material are typical of garben formations.

Climate and hydrology

The climate of this area is temperate and semi-arid with well-defined seasons. As depicted in Figure A-3 for two weather stations near the Little Bear River basin, the winters are long and relatively cold while summers are rather short, but also relatively cool. Average monthly precipitation seen in Figure A-4 for the annual cycle for the two stations, is distributed in a manner typical of the western intermountain area, with most of the precipitation occurring during the fall, winter, and spring months, leaving the summer months dry. As shown by Figure A-5, the normal annual average precipitation is distributed roughly in proportion to elevation with the greatest depths accumulating at the higher altitudes on the watershed, while the valley floor experiences much lighter precipitation.

Surface runoff occurs largely during the snowmelt months of April, May, and June as is typical of the high mountain watersheds of the west; Figure A-6 shows the annual distribution of runoff at two stations.

Canal diversion

Several [illegible]on companies maintain canal systems in the area, [illegible] in aggregate about 52,055 acre-ft annually, exclu[illegible] of the trout farm diversion. Flow measurements on each canal are taken at weekly intervals by the Little Bear River Water Commissioner and published in his annual report to the Utah State Engineer. Table B-1 identifies the various canals in the project area and summarizes annual diversion amounts. Figure A-7 shows the canals as they fit into the configuration of the area.

Reservoirs

The two reservoirs in the system are Hyrum and Porcupine shown in Figure A-1. Hyrum Reservoir was

Table A-1. Characteristics of Little Bear River system, Cache Valley, Utah.

Reach	Station Designation	Discrete Inputs	Diversions	Diffuse Inputs	Annual Flow 1967 acre feet		August Flow 1967		BOD Level mg/L	Other Quality Charts	Uses	Trout Production
					canals	streams	canals	streams				
B7	S0.0-S12.7					74,570		2,020	1-3	2-5 mg/L NO_3 10^4-$6x10^5$ col/ml		
		Wellsville Sewer & Spring							2-5	2-5 mg/L NO_3 10^4-$6x10^5$ col/ml		
B2	S12.7-S16.0		Wellsville-Mendon Upper	Irrigation Return Flow Springs, G.W.	3,031	57,680	591	159	2-5	10^3-10^5 col/ml	Irrigation	
			Wellsville-Mendon Lower		10,903		2,565					
			Eastfield Canal		8,126		2,010					
			Lt. Feeder Dit.		1,149		317					
			Darley Ditch		589		117					
B3	S16.0-S19.0	Hyrum Res. 15,280 acre ft. usable capacity								Bluegreen algae	Irr. Storage Fishing Boating Swimming	
B4	S19.0-S21.3					80,390		3,910	2-14	heavy sphaerotolus 10^4-$2x10^6$ col/ml 1-4 NO_3^-	Waste carrier	
B5	S21.3-S25.0	Trout Farm	Trout Farm								Fishing	1,500/mile
B6	S25.0-S27.0		Hyrum Canal		10,442	46,450	1,615	2,160	1-4	10^3-10^6 col/ml		
B7	S27.0-S29.0					17,650		847	1-3	0-1 mg/L NO_3^- 10^3-$2x10^5$ col/ml	Fishing	
B8	S29.0-S35.0			Springs								
D7	SD0.0-SD2.0								0.2-2.0	0-1 mg/L NO_3^- $5x10^2$-$4x10^5$ col/ml	Fishing	
D2	SD2.0-SD6.0											
E1	SEC0.0-SEC4.3		Paradise Canal		11,239		2,034		1-2	0-1 mg/L NO_3^- 10^2-$3x10^5$ col/ml	Fishing Irrigation	
			High Line Canal		6,576		1,295					
E2	SEC4.3-SEC6.2	Porcupine Res. 12,800 acre ft. usable capacity									Fishing Storage	
E3	SEC6.2-SEC8.0					29,170		938	0-2	0-.8 mg/L NO_3^- $8x10^2$-$8x10^4$ col/ml	Fishing Picnicking	300/mile
E4	SEC8.0-SEC12.0											
	TOTALS		Total Canal Diversions (1967)		52,055		10,544	Total acres irrigated = 13,038				

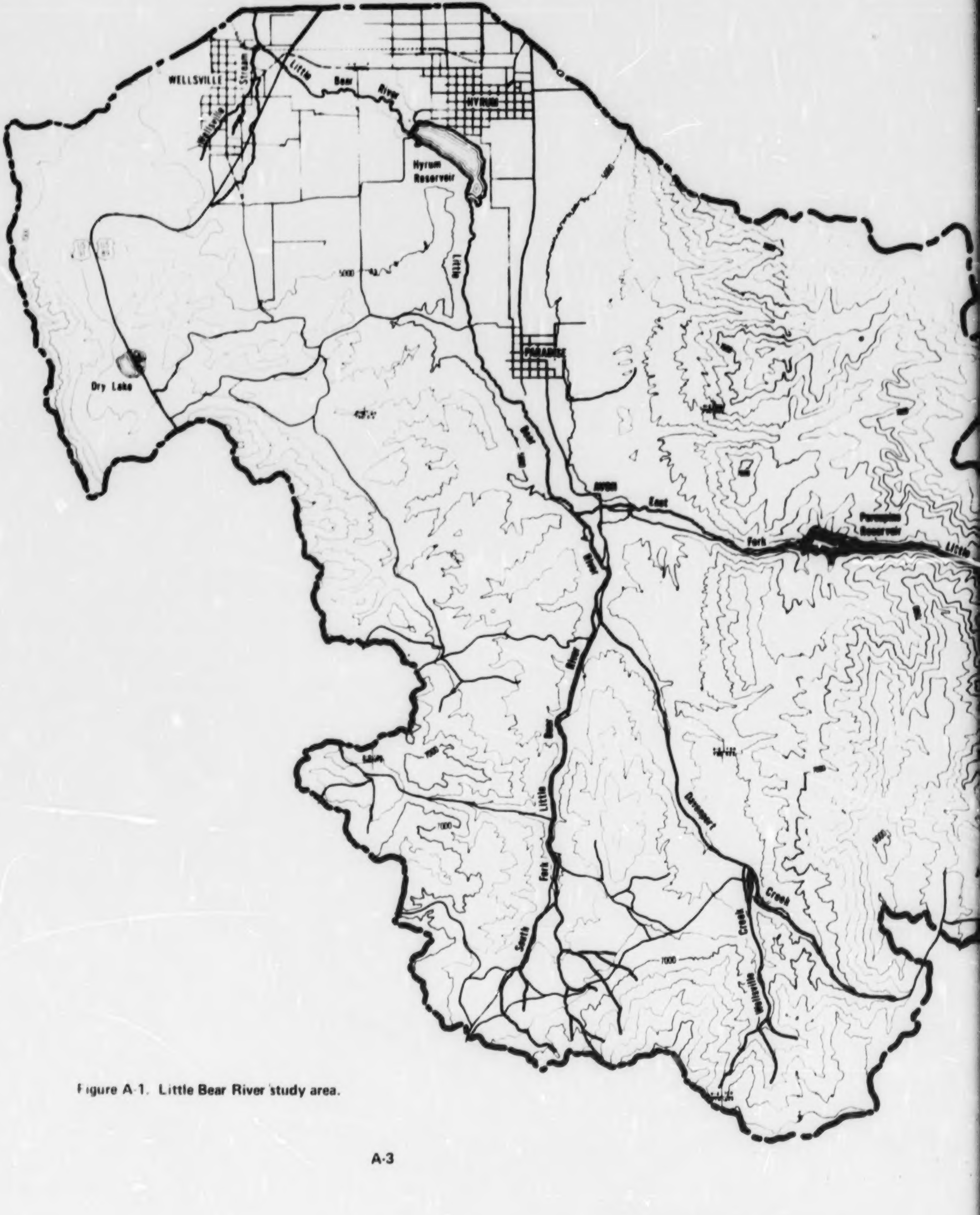
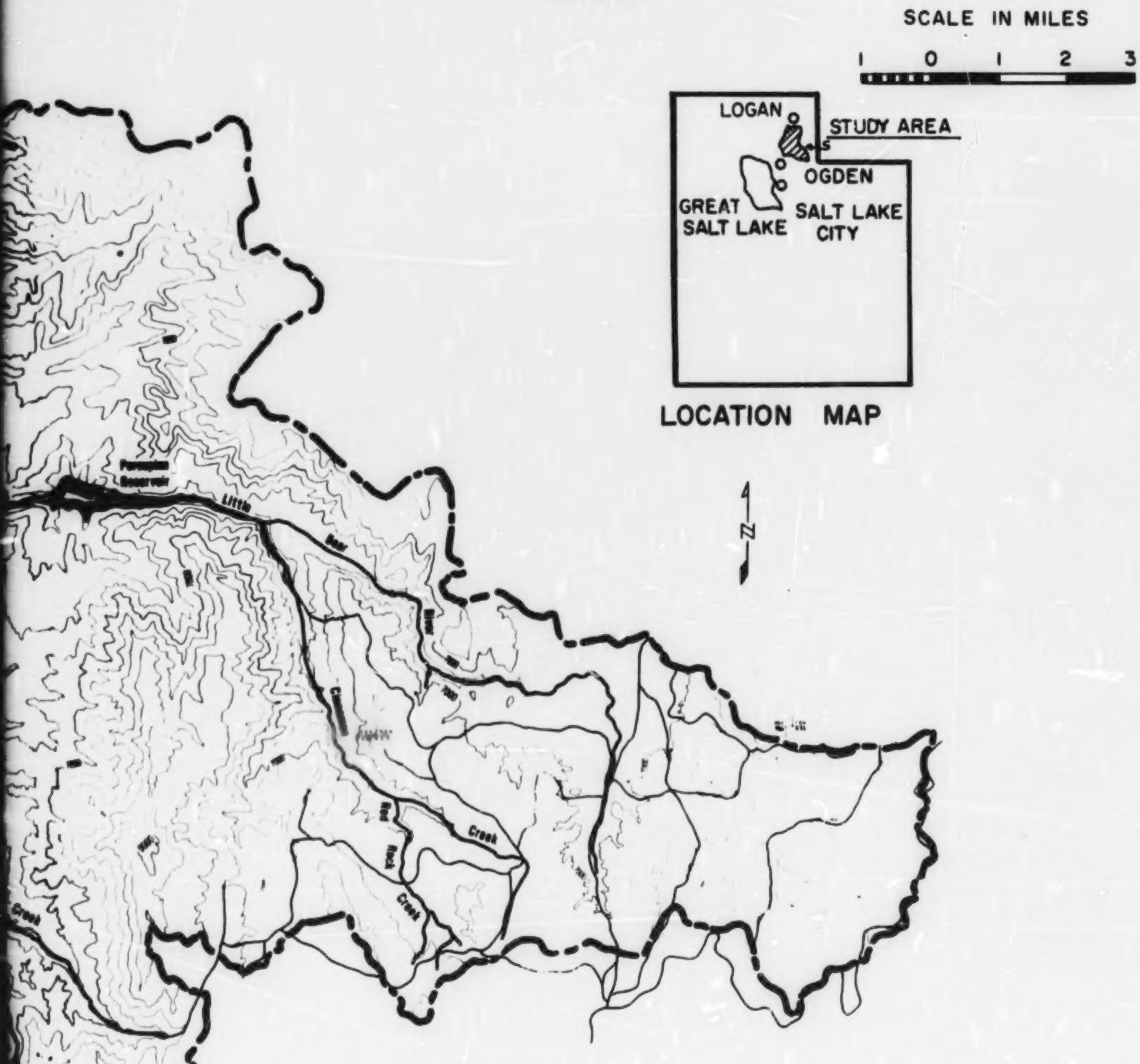

WELLSVILLE
Wellsville
Stream
Little
Bear
River
HYRUM
Hyrum
Reservoir
5000
Little
PARADISE
Dry Lake
Bear
AVON
East
Fork
Porcupine
Reservoir
Little
River
Bear
Little
South
Fork
Davenport
Creek
Wellsville
Creek
7000
7000

Figure A-1. Little Bear River study area.

LITTLE BEAR RIVER STUDY AREA.


SCALE IN MILES
1 0 1 2 3
LOGAN
STUDY AREA
OGDEN
GREAT SALT LAKE
SALT LAKE CITY
LOCATION MAP
N
Porcupine Reservoir
Little Bear River
Red Rock Creek
Creek
Creek

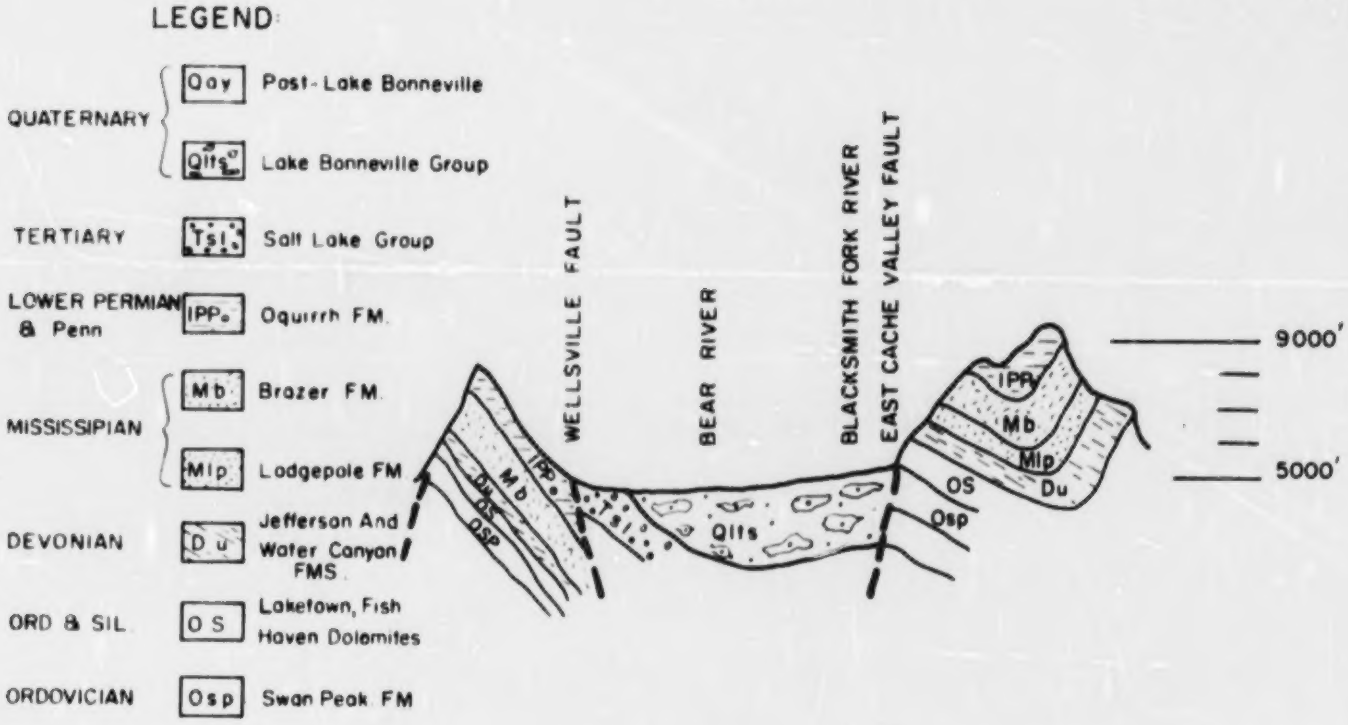
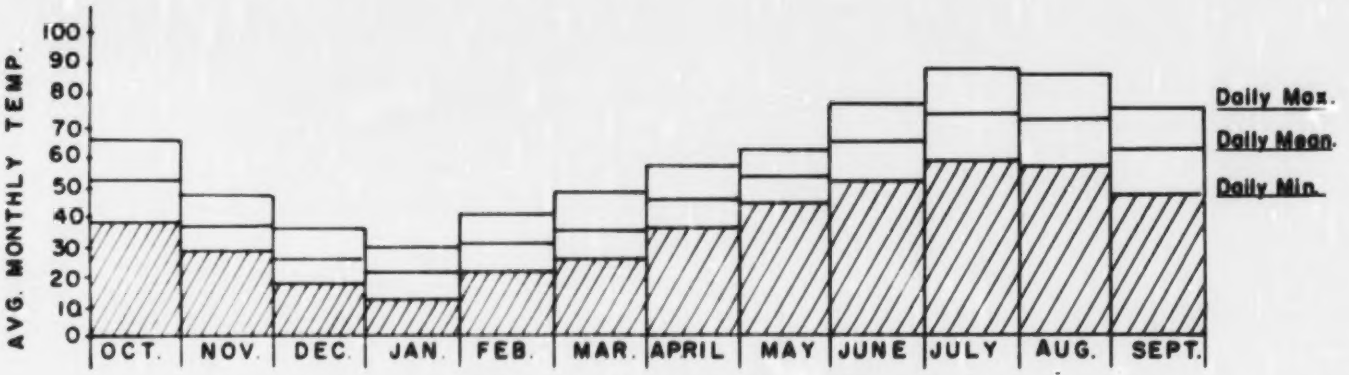
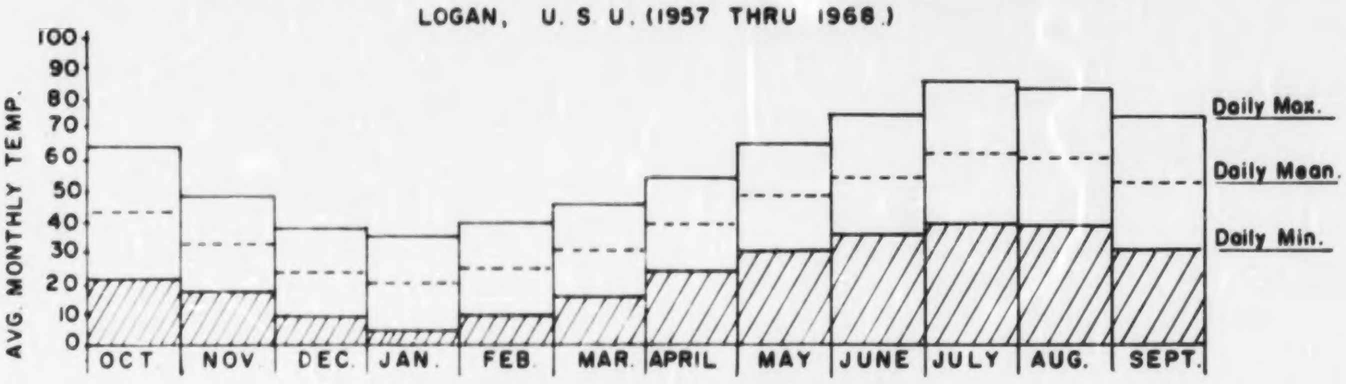

LEGEND
QUATERNARY
Qay Post-Lake Bonneville
Qlts Lake Bonneville Group
TERTIARY
Tsl Salt Lake Group
LOWER PERMIAN & Penn
IPPo Oquirrh FM.
MISSISSIPIAN
Mb Brazer FM.
Mlp Lodgepole FM.
DEVONIAN
Du Jefferson And Water Canyon FMS.
ORD & SIL.
OS Laketown, Fish Haven Dolomites
ORDOVICIAN
Osp Swan Peak FM
WELLSVILLE FAULT
BEAR RIVER
BLACKSMITH FORK RIVER
EAST CACHE VALLEY FAULT
IPPo
Mb
Du
OS
OSP
Tsl
Qlts
Mlp
Osp
9000'
5000'

Figure A-2. Representative east-west geologic section of Cache Valley and watershed.

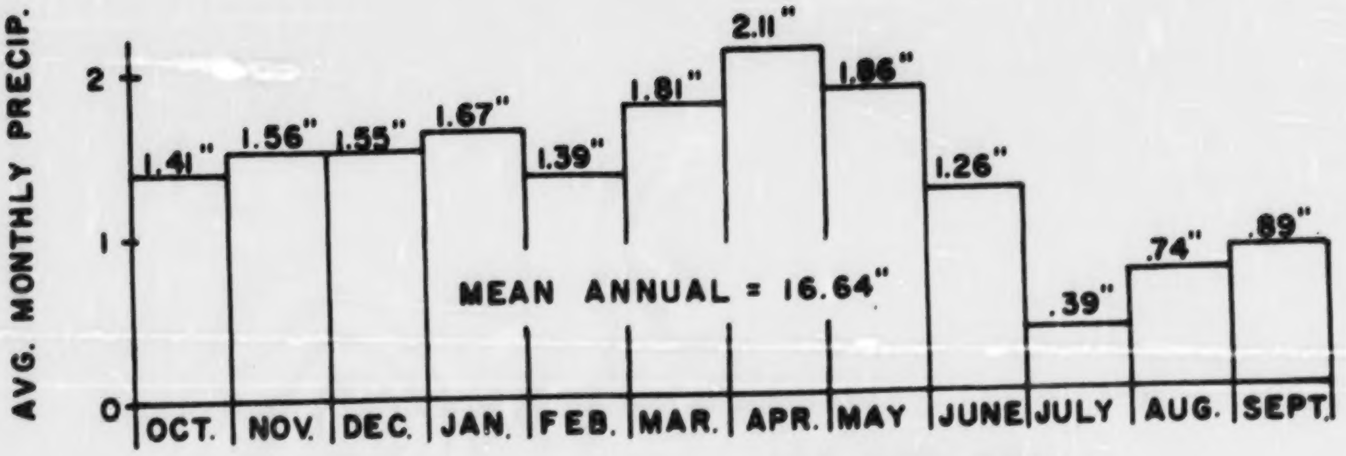


LOGAN, U. S. U. (1957 THRU 1968.)

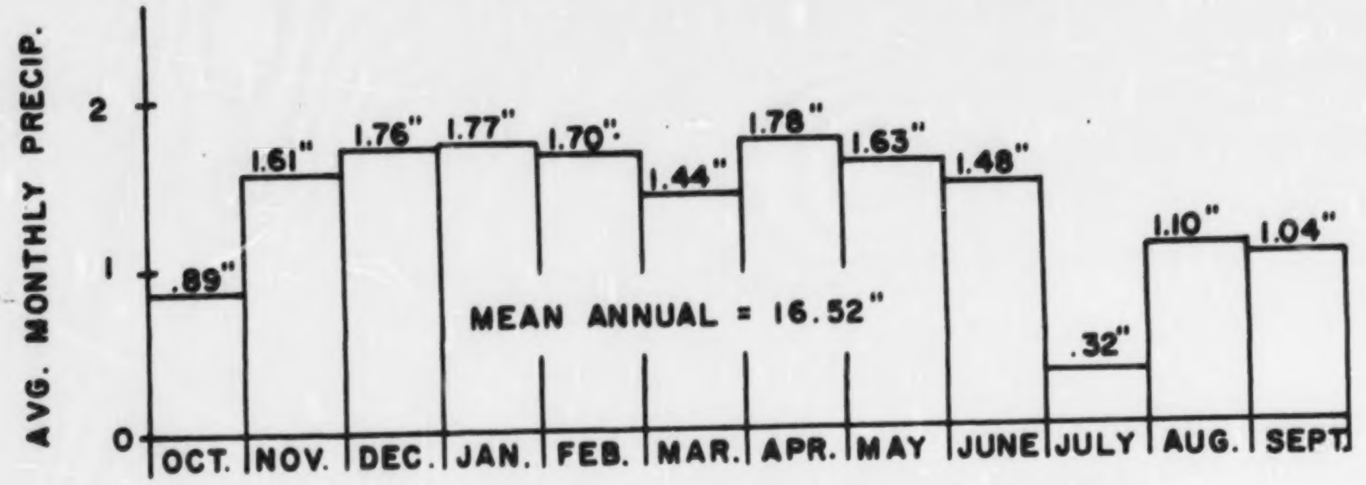


HARDWARE RANCH (1957 THRU 1968)

Figure A-3. Average monthly atmospheric temperatures for stations near the Little Bear River basin.



LOGAN: U.S.U. (1939 THRU 1968)



HARDWARE RANCH (1956 THRU 1968)

Figure A-4. Average monthly precipitation for stations near the Little Bear River basin.

completed in 1935 by the U.S. Bureau of Reclamation for irrigation. The usable pool contains 15,280 acre-ft of storage. Porcupine was completed in 1961 and contains 12,800 acre-ft of usable storage.

Cultural development

The early development of Cache Valley is intimately interwoven with the expansion of the Mormon settlements in Utah during the 1850's. The first white men to enter Cache Valley were such people as Bridger, Fremont, and Stansbury. The town of Wellsville was among the first permanent settlements established in Cache Valley in 1855 and 1856.

Even as today, the major activities in the early days of Cache Valley (and the Little Bear River basin) were those of sheep and cattle ranching and dairy farming. At the present time, the economy of the study area is almost exclusively agricultural, supplemented by agriculture related industries such as meat packing, cheese making, and trout farming. Many of the residents of the area find employment at nearby Utah State University and in industries and commercial establishments to be found in the surrounding area.

Highway access to the area is afforded by U.S. Highway 89-91 past Wellsville and state highway 163 south past Hyrum, through Paradise to Avon. The several private and U.S. Forest Service development roads provide easy access to the watershed area.

Rail connections are limited to a spur line passing through Hyrum and Wellsville which connect communities as far north as Preston, Idaho, to the main line between Pocatello, Idaho, and Ogden, Utah.

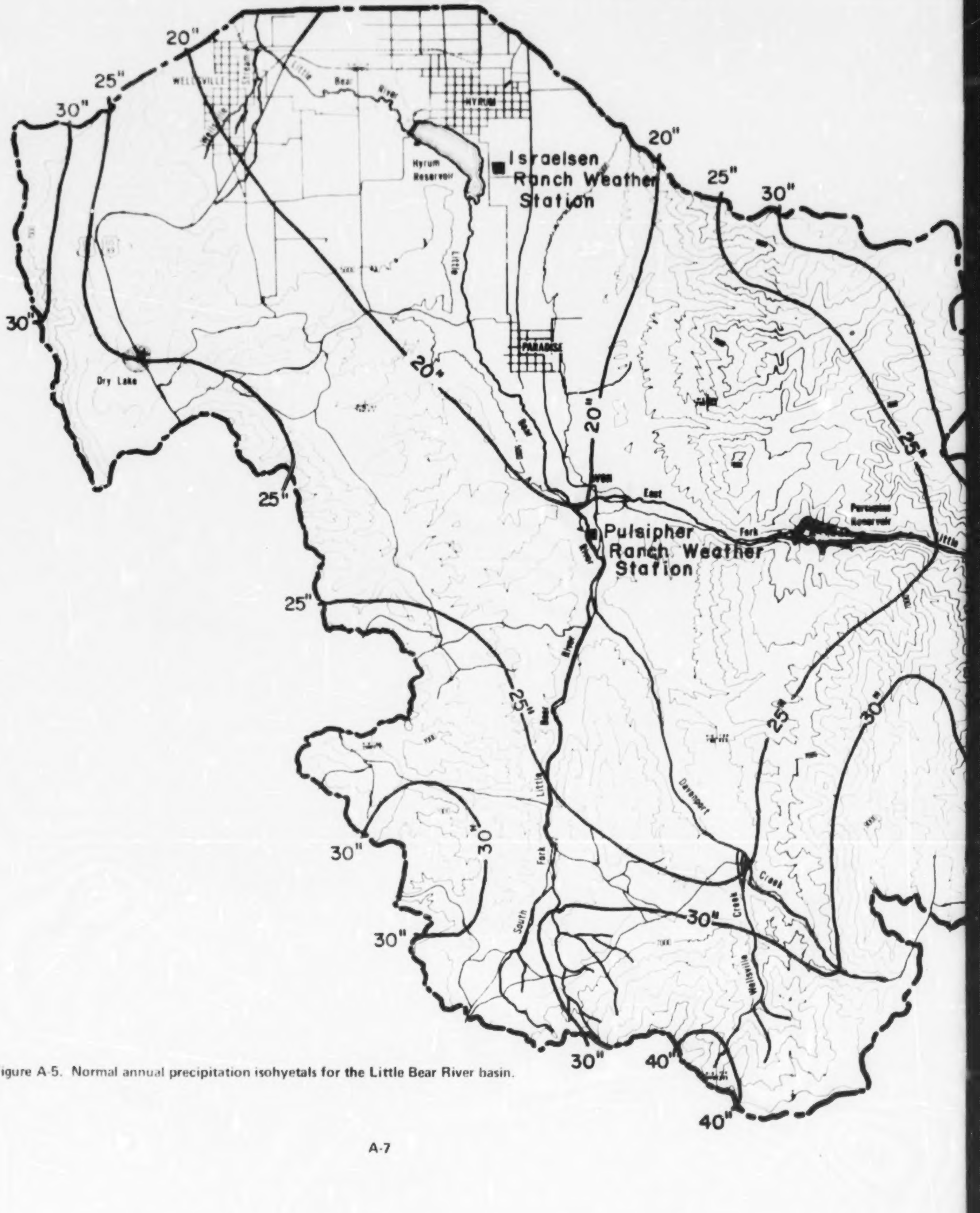
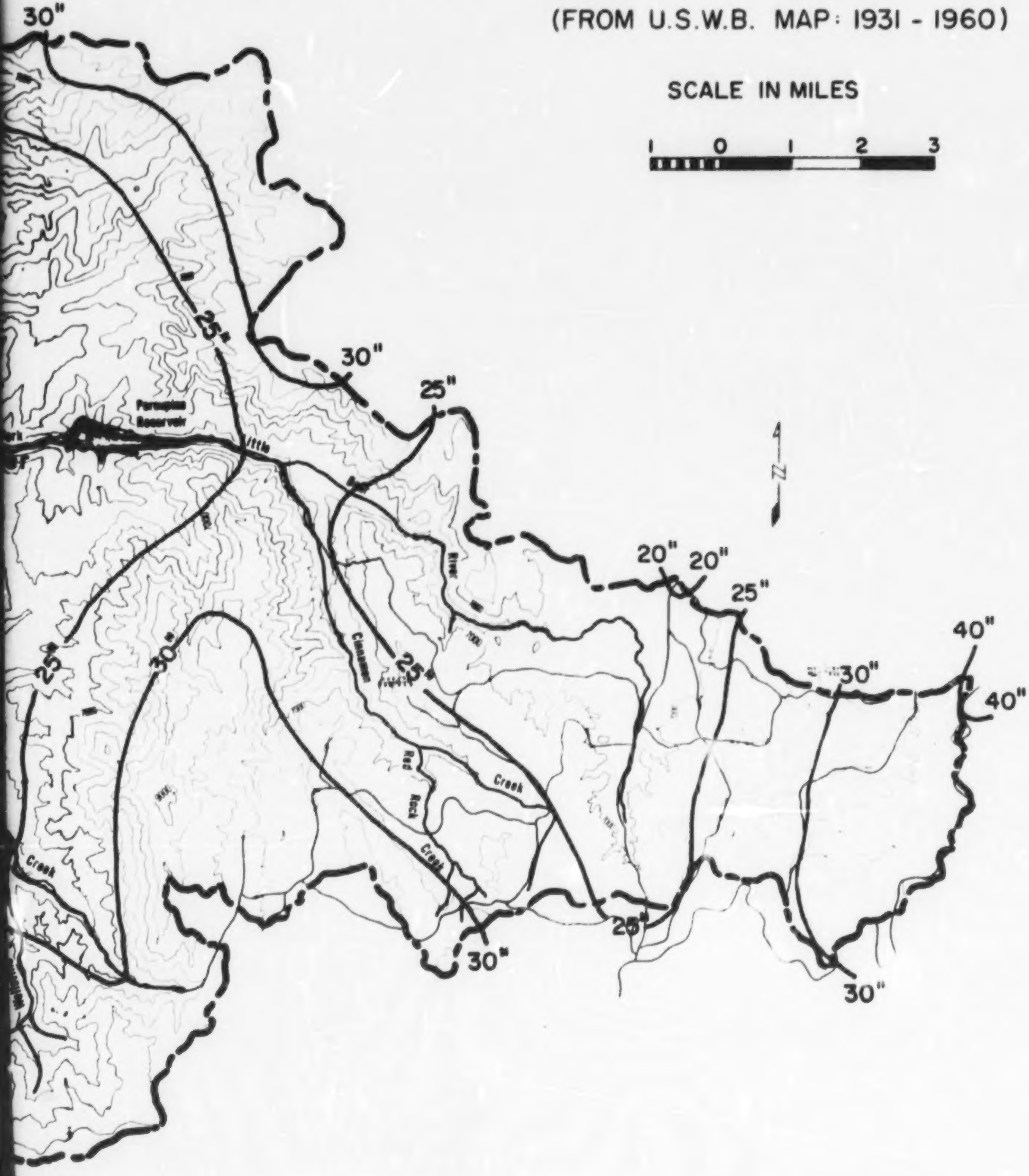

20"
25"
30"
WELLSVILLE
Little Bear River
HYRUM
Hyrum Reservoir
Israelsen Ranch Weather Station
20"
25"
30"
30"
PARADISE
Dry Lake
20"
20"
25"
25"
East Fork
Porcupine Reservoir
Pulsipher Ranch Weather Station
25"
Little Bear River
25"
30"
Davenport Creek
30"
30"
South Fork Little
30"
Wellsville Creek
30"
40"
40"

Figure A-5. Normal annual precipitation isohyetals for the Little Bear River basin.

NORMAL ANNUAL PRECIPITATION ISOHYETALS FOR THE LITTLE BEAR RIVER BASIN.

(FROM U.S.W.B. MAP: 1931 - 1960)


SCALE IN MILES
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N
30"
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25"
40"
30"
40"
25"
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25"
30"
30"
Porcupine Reservoir
Little
River
Cinnamon
Creek
Red Rock
Creek
Creek

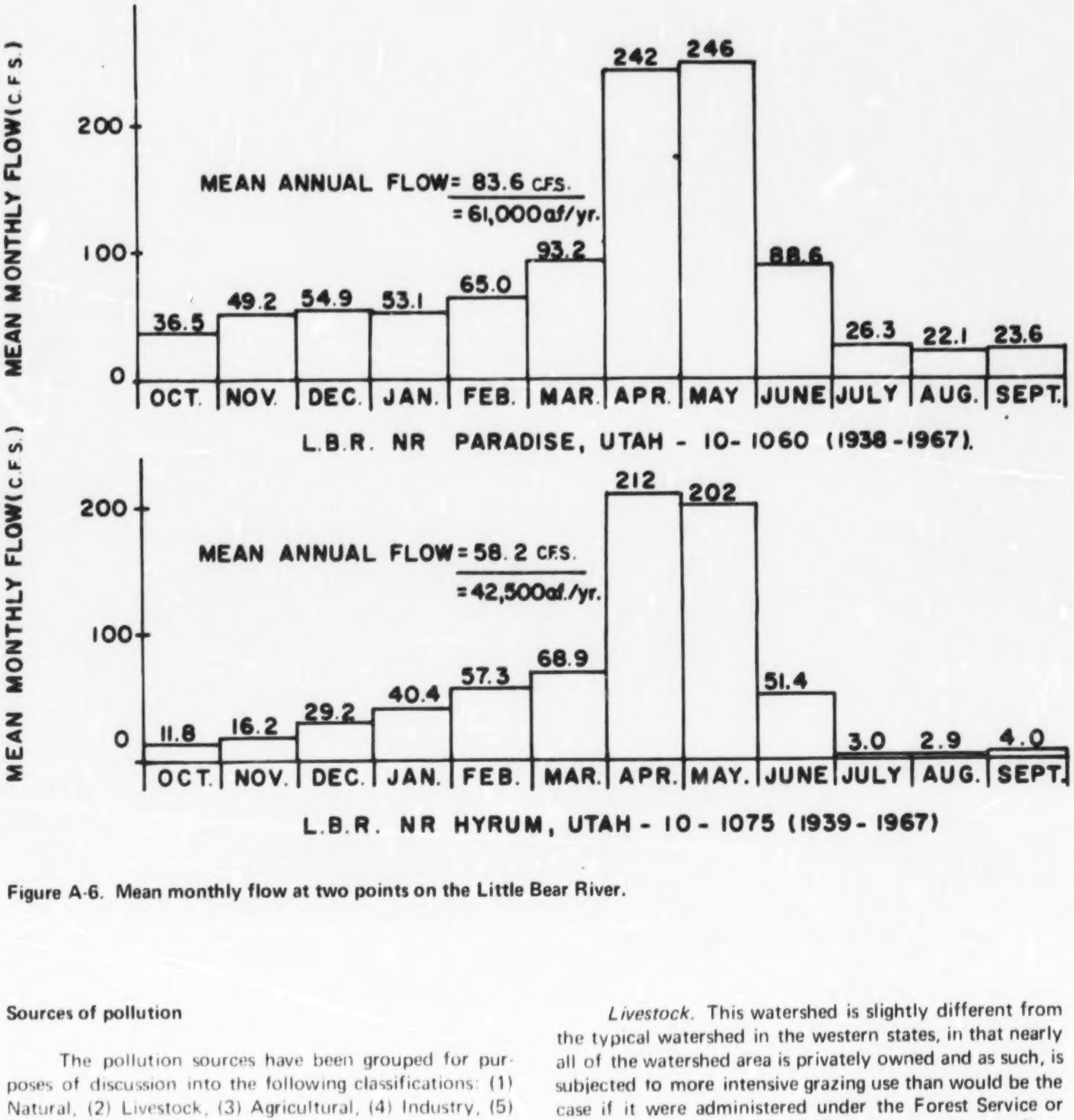


Figure A-6. Mean monthly flow at two points on the Little Bear River.

Sources of pollution

The pollution sources have been grouped for purposes of discussion into the following classifications: (1) Natural, (2) Livestock, (3) Agricultural, (4) Industry, (5) Municipal, (6) Garbage Dumps, and (7) Recreation. Table A-1 summarizes some of the quality characteristics of the stream which are associated with some of these effects. Values shown are based upon project data; they are incomplete and included only for the purpose of providing some additional perspective concerning stream quality.

Natural. Natural pollution is composed of the pollutional effects of the solution of minerals from geological formations of the watershed and water courses, natural death and decomposition of native plant matter, and organic inputs from wildlife inhabiting the area.

Livestock. This watershed is slightly different from the typical watershed in the western states, in that nearly all of the watershed area is privately owned and as such, is subjected to more intensive grazing use than would be the case if it were administered under the Forest Service or Bureau of Land Management programs. In the valley floor area, livestock grazing is quite general, much of it being irrigated pasturage of dairy herds.

The mountainous watershed areas are quite extensively used for sheep and cattle grazing during the summer months. Estimated numbers and distribution by month are listed in Table A-2. Most of the sheep grazing is not in areas adjacent to flowing streams. During seasons when the sheep are being moved onto or off of the range, there may be short periods when they would be concentrated in

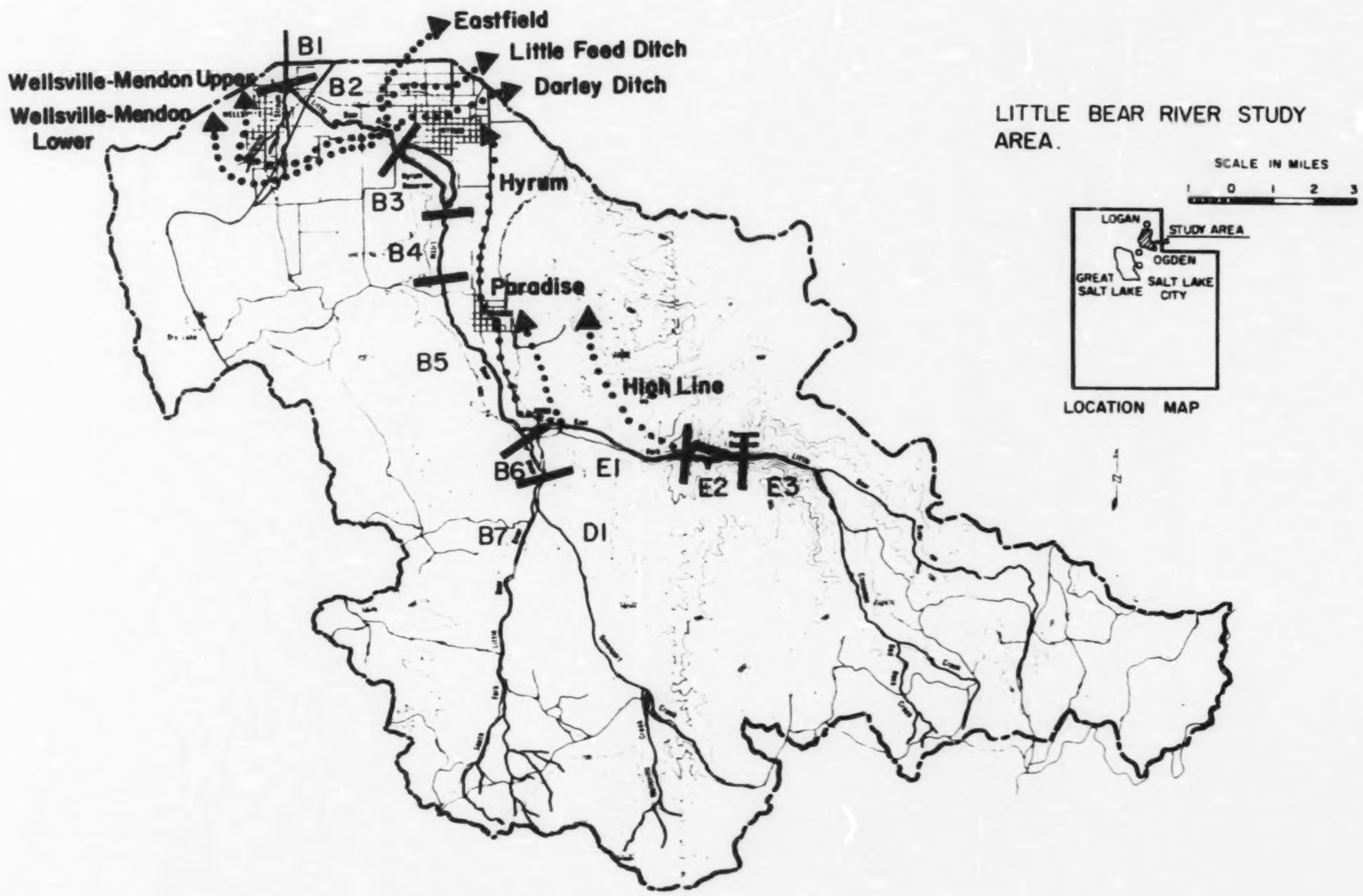

Eastfield
Little Feed Ditch
Darley Ditch
B1
B2
Wellsville-Mendon Upper
Wellsville-Mendon Lower
B3
B4
Hyrum
Paradise
B5
High Line
B6
E1
E2
E3
B7
D1
LITTLE BEAR RIVER STUDY AREA.
SCALE IN MILES
1 0 1 2 3
LOGAN
STUDY AREA
OGDEN
GREAT SALT LAKE
SALT LAKE CITY
LOCATION MAP
N

Figure A-7. Canal system for Little Bear River system.

Table A-2. **Grazing use patterns on watershed area (above 5000 ft.).**

	May	June	July	August	Sept.	Oct.	Nov.
Sheep	12,000	8,800	7,100	6,500	6,300	9,000	3,600
Cattle	150	500	515	465	455	590	150

the vicinity of flowing streams thus being in a position to add to the pollution load of the stream. Sheep are not, however, considered to be a significant source of stream pollution. Cattle, on the other hand, tend to shade-up in the canyon bottoms during the heat of the day and move out to the hillsides during evening and morning hours to graze. This pattern of behavior tends to allow greater contribution to the organic pollution of streams.

The estimation of numbers of livestock is considerably more difficult in the farm lands of the valley floor area because of the large number of property owners involved. Because only animals confined to pastures immediately adjacent to the flowing streams are expected to contribute significantly to the organic pollution of the streams, estimates have been prepared in Table A-3, which covers only these portions of the area.

Table A-3. Estimated livestock numbers in pastures immediately adjacent to streams.

Kind of stock	Total numbers
Cattle	1,200
Sheep	50
Horses	25
Hogs	800

Agriculture. The agriculture of this area is basically the same as that of the rest of Cache Valley, which is oriented primarily toward livestock production. Hay, grain, pasture, and corn are the prevalent crops produced in the area. Both irrigated and dry-farm agriculture are practiced. Irrigated land accounts for about 7100 acres of the cropped land in the valley area. The 4900 acres of dry-farmed land is generally located on the higher bench areas next to the mountain portion of the watershed.

Industry. Prominent industries in the area include: (1) two meat packing plants and a rendering plant near Hyrum, (2) a cheese plant at Wellsville, and (3) a trout farm at Paradise. Drainage from the area of the meat packing and rendering plants goes out through sloughs on the valley floor north and west of Hyrum toward Wellsville. Waste stabilization ponds have recently been constructed to treat liquid wastes from the meat packing and rendering plants. Liquid wastes from the cheese plant in Wellsville are discharged to the Wellsville sewer system, which enters the Little Bear River untreated just above station S-12.5. Water for the trout farm near Paradise is diverted from the river above Paradise. Additional water is obtained from natural springs. Wastes are discharged directly into the stream in the vicinity of station S-21.3.

Municipal. There are three municipal entries within the watershed: Hyrum, Wellsville, and Paradise. These towns get their water either from wells or from springs in the nearby canyons. Only Wellsville has any sewer system. This system serves about one third of the 1475 population. The population of Hyrum is 2100, while that of Paradise is 549. Septic tanks serve as the means of waste disposal employed in these communities as well as in the more rural locations.

Garbage dumps. Open garbage dumps are maintained by Hyrum, Wellsville, and Paradise. The Paradise dump is located on the west side of the river in the mouth of McMurdie Hollow. The Hyrum garbage dump is south and west of Hyrum Reservoir. Wellsville's dump is adjacent to the river just north of the project boundary, but above the quality monitoring station at S-12.5. The locations of all three of these open dumps are immediately adjacent to the Little Bear River surface drainage and interflow from these dumps toward the stream.

Recreation. Recreational use of the watershed consists of fishing on the streams and reservoirs of the system, boating and other water-based sports on Hyrum Reservoir and Porcupine Reservoir and camping along the streams in the mountainous areas. Hyrum State Park, consisting of beach development, boat launching and picnic facilities is located on the southeastern shore of Hyrum Reservoir. This is a popular recreational site; Wennergren (1965) reports a total of 2537 boat launchings at Hyrum Reservoir during 1963. Water-based recreation on Porcupine Reservoir is somewhat hindered by the program under which the reservoir is operated, which results in wide seasonal variations in water level with associated problems of access. It does receive considerable weekend fishing pressure, however. The recreational use of Hyrum Reservoir has dropped sharply after August 1 for the past several seasons, due to algae blooms. The bloom was particularly acute in the 1969 season and visitations after August 1 were negligible by comparison with earlier in the season.

Fishing activity in Hyrum Reservoir drops later in the season also as the trout develop parasite infections, which though not harmful to humans, are aesthetically objectionable.

APPENDIX B

DATA COLLECTION SYSTEM

The four major components of the data collection system are: (1) stream gaging; (2) weather observation; (3) weekly quality sampling; and (4) continuous quality monitoring. Each of these phases of the data acquisition system will be discussed subsequently.

Stream gaging

Surface flows within the basin are well monitored and documented. During the data acquisition phase of the project the U.S. Geological Survey (USGS) operated six active stream gaging stations on the Little Bear River and its tributaries and two on irrigation canals leaving the study area at the north boundary; locations are shown in Figure B-1. A reservoir level gage is also maintained at Hyrum Reservoir. Table B-1 lists the gaging installations and periods of record. Gages 10-1046, 10-1076, 10-1072 and 10-1074 were installed and operated by the USGS under contract with this project. The level of Porcupine Reservoir is read only intermittently by a manometer.

Weather observation

The United States Weather Bureau (USWB) does not maintain a weather observation station on the Little Bear River basin. Meteorological records from three observation stations in and near Logan, Utah, are published in USWB records. These stations are designated as Logan radio KVNU, Logan Utah State University and Logan Utah State University Experiment Station. Another USWB station is located at Hardward Ranch to the north and east of the project area.

To supplement the information available from the above meteorological stations, two weather observation stations were established within the project area. The locations of these stations are shown on Figure A-5. Weather observation stations are listed in Table B-2, which indicates the types of measurements and periods of record. Also the Soil Conservation Service maintains several snow survey courses along the southern boundary of the project area.

Weekly quality sampling

Surface water quality sampling points have been established at intervals from the north boundary upstream to Davenport Creek on the main stem and above Porcupine Reservoir on the East Fork as shown in Figure B-2. Table B-3 gives names, coordinate locations, and periods of sampling for sampling locations established under this project. Samples were collected weekly.

Table B-1. Surface water gaging stations.

Number	Name	Drainage area (sq. mi.)	Period of record
10-1046	South Fork L.B.R. nr. Avon, Ut.	26.0	Jul'66-Sept'68
10-1047	L.B.R. below Davenport Ck. nr. Avon, Ut.	62.1	Oct'60-date
10-1049	E. Fk. L.B.R. above Porcupine Res. nr. Avon, Ut.	58	Oct'63-date
10-1060	L.B.R. nr. Paradise, Ut.	203	Jan'37-date
10-1070[a]	Hyrum Res. nr. Hyrum, Ut.	220	Oct'38-date
10-1072	Wellsville-East Field Canal nr. Hyrum, Ut.		Jul'66-Sept'68
10-1074	Wellsville-Mendon Lower Canal at Wellsville, Ut.		Jul'66-Sept'68
10-1075	L.B.R. nr. Hyrum, Ut.	222	Oct'38-date
10-1076	L.B.R. at Wellsville, Ut.	245	Jul'66-Sept'68

[a] Reservoir contents (acre-feet)

Table B-2. Weather observation stations.

Station name	Location	Parameters measured[a]	Period of record
Logan radio KVNU[b]	Logan	P,T	1957-date
Logan Utah State Univ.[b]	Logan	P,T	1890-date
Logan Ut. St. U. Ex. Sta.[b]	Logan	P,T,E	1950-date
Israelsen ranch[c]	Hyrum	P,[d]T	Nov. 1966-Sept. 1969
Pulsipher ranch[c]	Avon	P,[d]T	Nov. 1966-Sept. 1969

[a] P = precipitation
T = temperature
E = evaporation

[b] USWB weather substations

[c] Project weather station

[d] Rainfall only

Table B-3. Little Bear River water quality sampling stations.

Station No.	Coordinates (Meters)	Description of Sampling Point	Period of Sampling
S-12.5	230112	At Wellsville Telemetry site	082967 - 031169
S-12.7	231109	400 feet downstream of confluence of Little Bear River and Wellsville Stream	060366 - 082367
S-12.8	232107	Adjacent to Wellsville lower road bridge	060366 - 031169
S-15.2	259003	Adjacent to Salt Lake Meridian road bridge	060366 - 031169
S-16.8	279084	On boat ramp at Hyrum State Park[a]	101166 - 031169[b]
S-20.5	287041	At Paradise Telemetry site	031268 - 031169
S-21.3	287028	Adjacent to bridge N.W. of Paradise	060366 - 041768
S-22.4	295012	At trout farm diversion	110867 - 071068
S-24.6	309984	Adjacent to bridge N.W. of Avon	060366 - 031169
S-27.0	324957	At USGS gaging station downstream from Davenport Creek	070766 - 031169
S-27.5	320944	At USGS gaging station upstream from Davenport Creek	070766 - 031169
SEC-0.4	323977	Adjacent to bridge south of Avon	112067 - 102268
SEC-4.3	376965	100 feet downstream from Porcupine Reservoir outlet	062967 - 111368[b]
SEC-6.2	405963	At USGS gaging station upstream from Porcupine Reservoir	062967 - 111368[b]
SD-0.0	323945	Adjacent to bridge crossing Davenport Creek	070766 - 031169
SW-0.1	229106	Adjacent to Wellsville lower road culvert	100466 - 031169
STF-0.0	288028	Above check structure	101166 - 031169

[a] Samples taken in open water near outflow during winter months of 1967 & 1968.

[b] Considerable missing data during winter months.

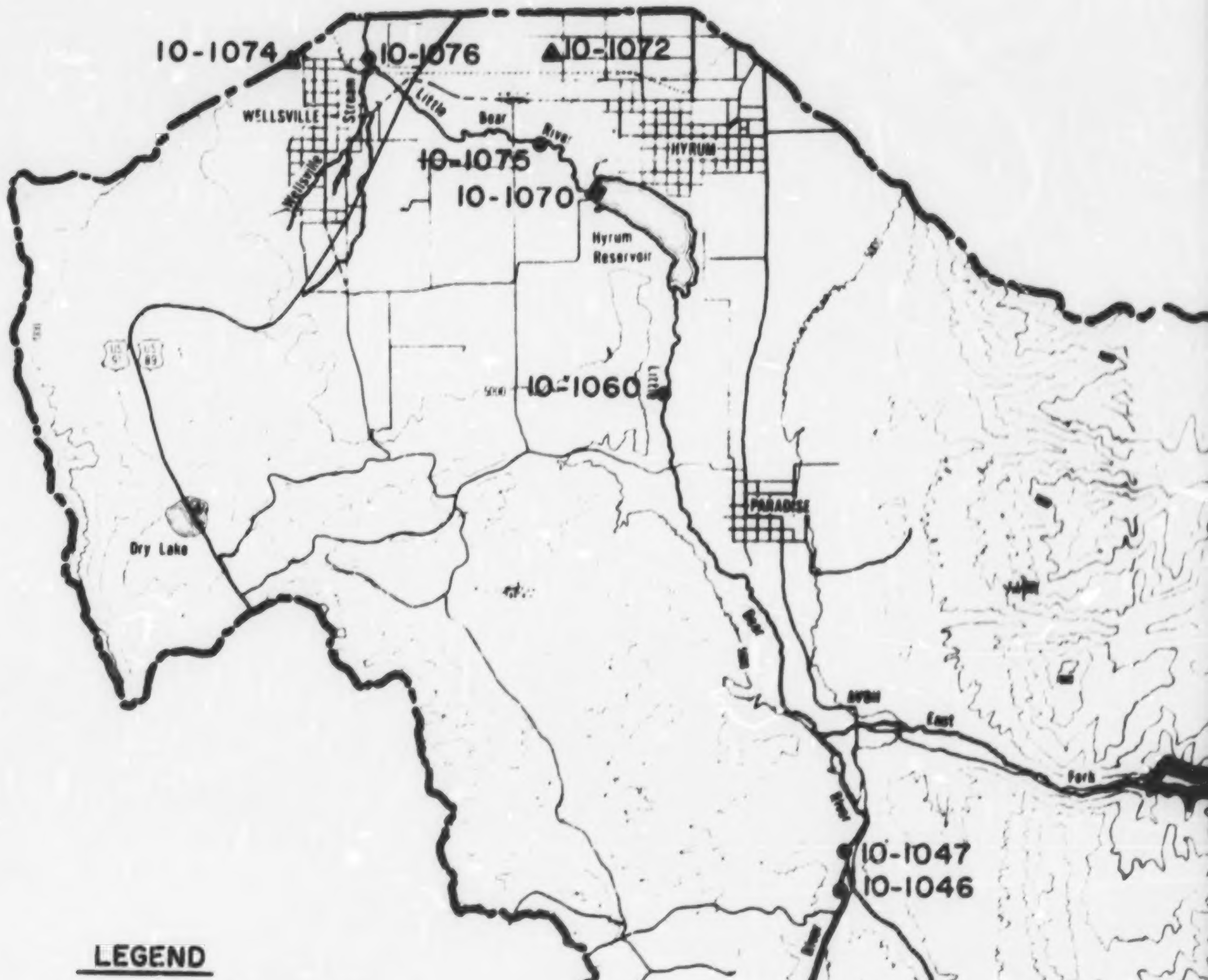
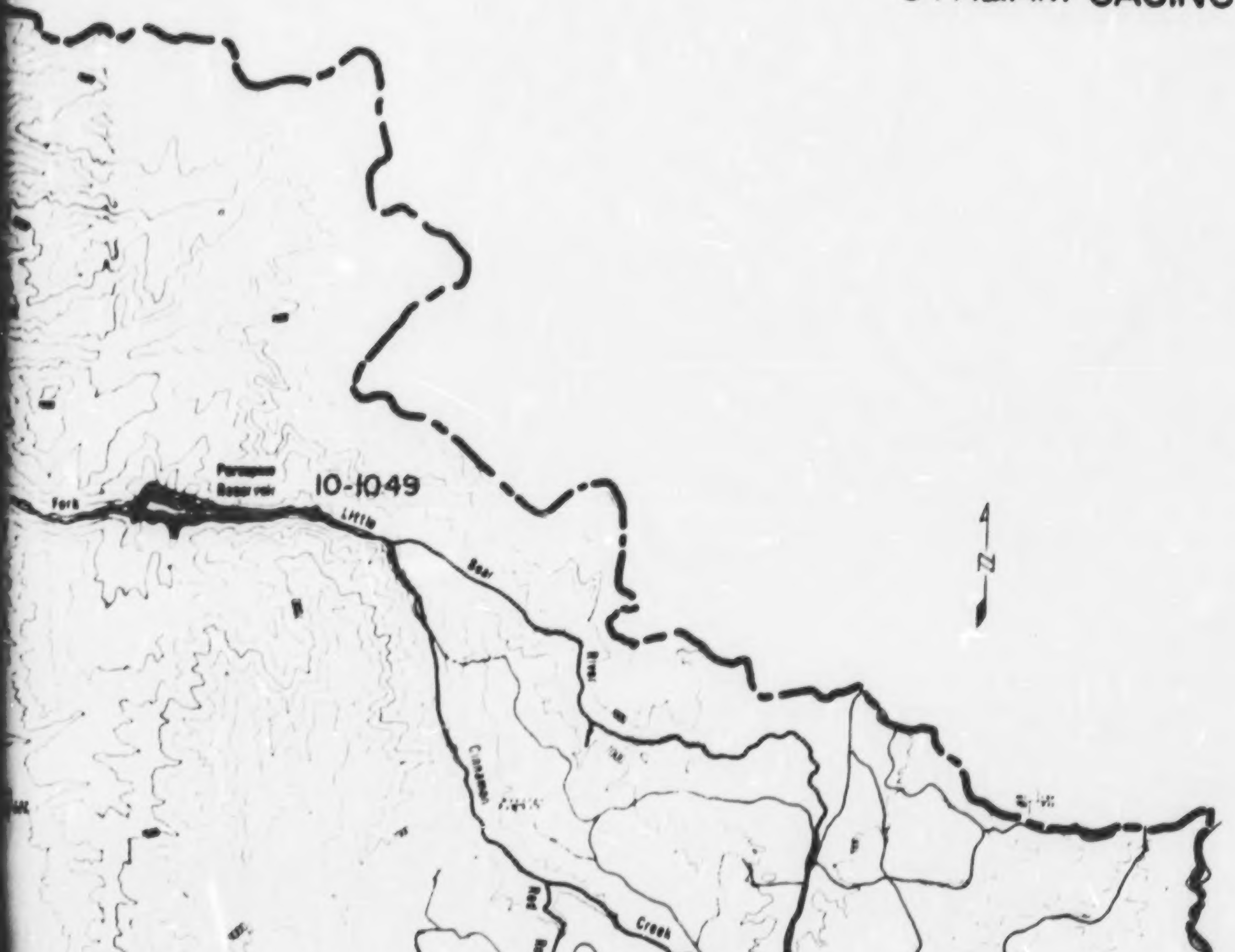

10-1074
10-1076
10-1072
WELLSVILLE
Wellsville
Stream
Little
Bear
River
HYRUM
10-1075
10-1070
Hyrum
Reservoir
10-1060
Little
PARADISE
Dry Lake
East
Fork
10-1047
10-1046
South
Fork
Little
Davenport
Creek
Wellsville
Creek
LEGEND
● U.S.G.S. Stream Gages
◆ Reservoir Level Gage
▲ Canal Gages

Figure B-1. Location of USGS stream gaging stations.

LOCATION OF U.S.G.S. STREAM GAGING STATIONS.


Fork
Porcupine Reservoir
10-1049
Little
Bear
River
Cinnamon
Creek
Red
Rock
Creek
Creek
Creek
N

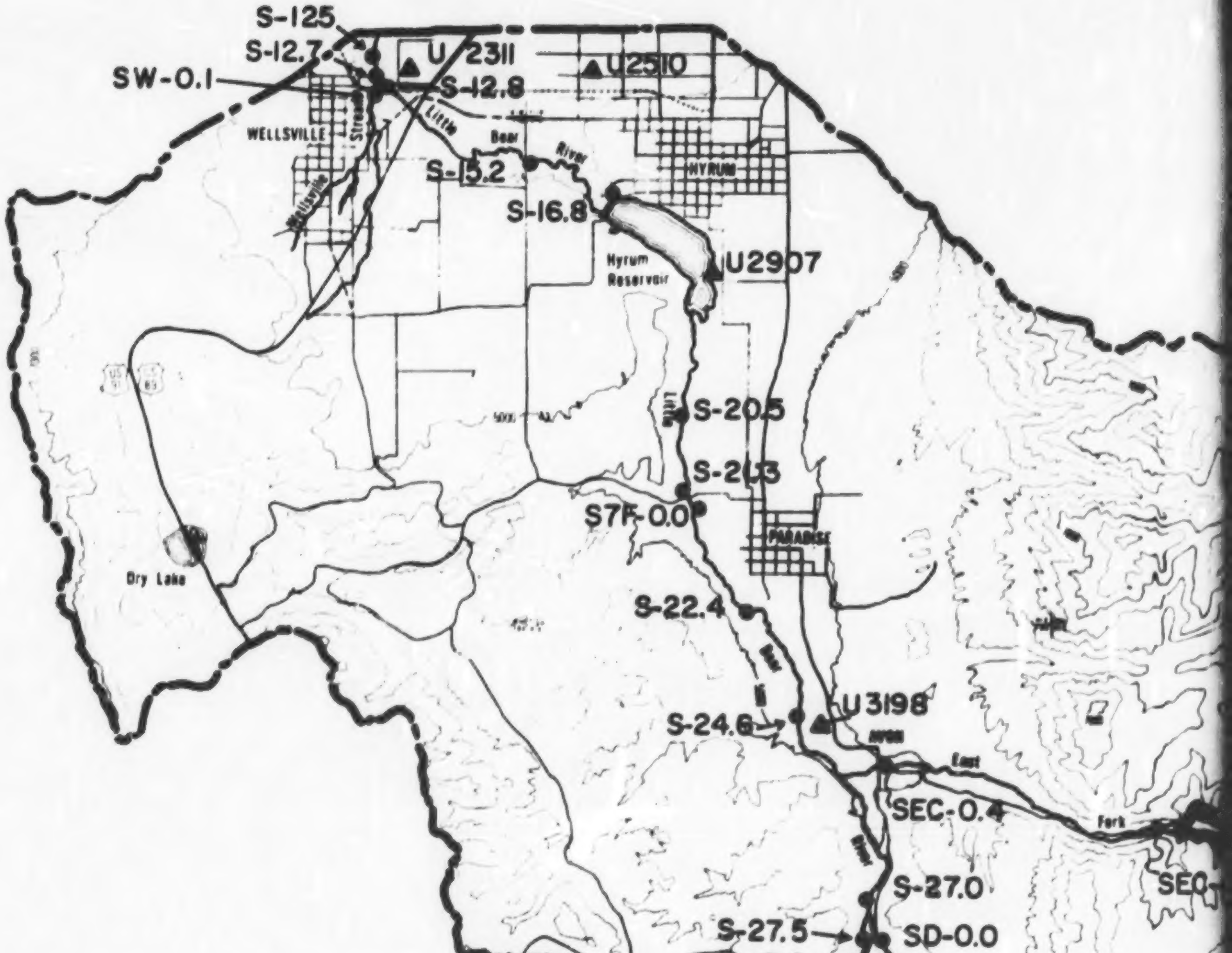
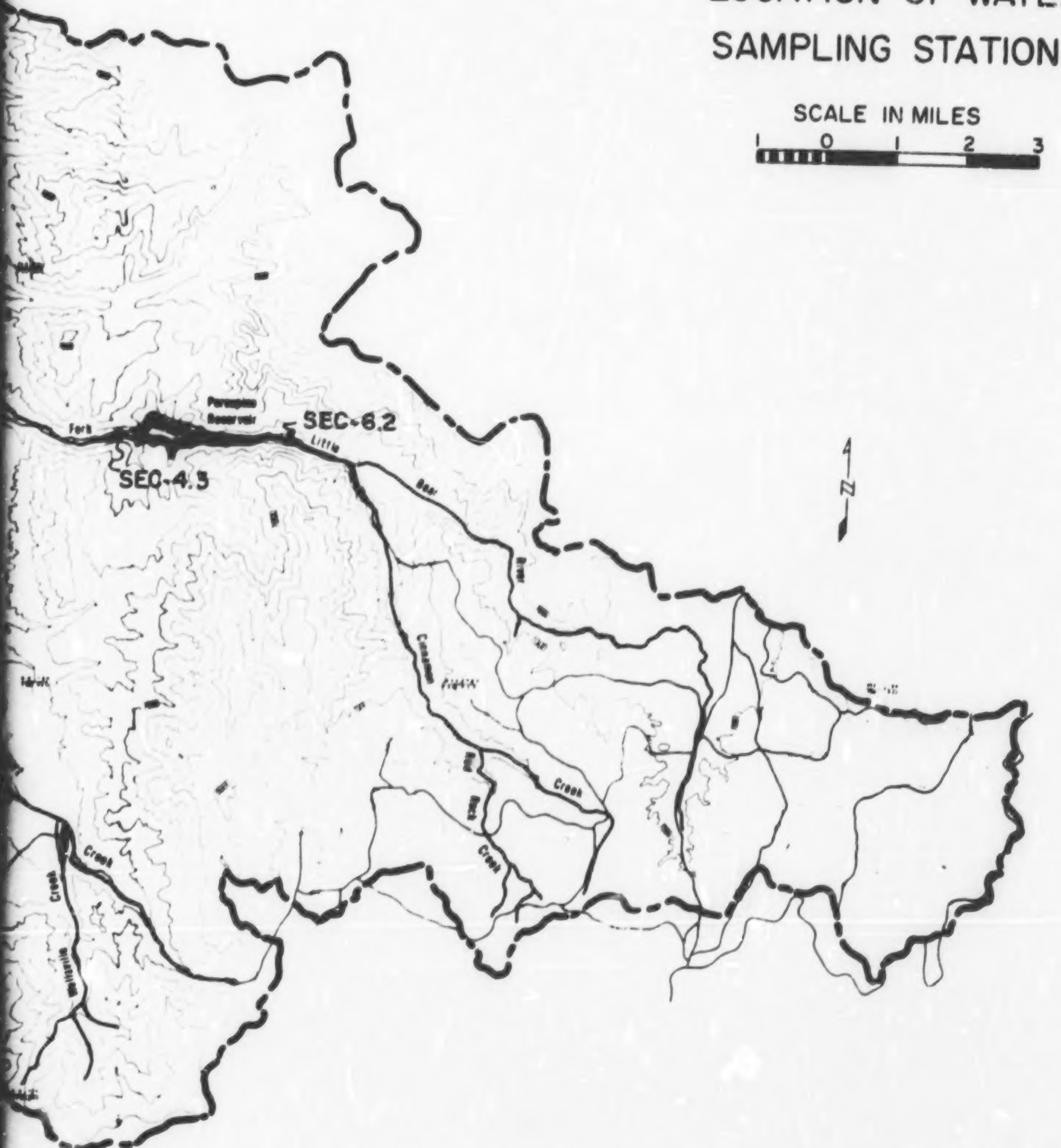

S-125
S-12.7
SW-0.1
U 2311
U2510
S-12.8
WELLSVILLE
Little
Bear
River
S-15.2
HYRUM
S-16.8
Hyrum Reservoir
U2907
US 91
US 89
5000
S-20.5
S-21.3
S7F-0.0
PARADISE
Dry Lake
S-22.4
U3198
S-24.6
AVON
East
Fork
SEC-0.4
SEC-
S-27.0
S-27.5
SD-0.0
7000
South
Fork
Little
Davenport
Creek
Wellsville
Creek

Figure B-2. Location of water quality sampling stations.

LOCATION OF WATER QUALITY SAMPLING STATIONS.


SCALE IN MILES
1 0 1 2 3
N
Porcupine Reservoir
SEC-6.2
Fork
SEC-4.3
Little
Bear
River
Creek
Creek
Creek
Creek
Creek
Wellsville

Groundwater quality sampling points were established at four locations in the valley floor area, as shown in Figure B-2. These sampling sites are described in Table B-4. Groundwater samples were taken at monthly intervals.

In setting up the water quality monitoring network it was necessary to consider such factors as accessibility and winter conditions in addition to the obvious requirement of sampling to indicate sources of pollution and stream reaction to this and external factors. Those stations for which winter access was limited were sampled as conditions permitted. Station SEC 6.2 above Porcupine Reservoir was sampled irregularly during winter months due to the road being snowbound.

Continuous quality monitoring

Continuous water quality monitoring stations were installed at stations S-12.5 below Wellsville and S-20.5 near Paradise in cooperation with a water quality telemetry project at Utah Water Research Laboratory (Woffinden and Kartchner, 1968). The initial intent was to provide continuous strip chart recording at both sites, but excessive power consumption of the system installed at the Paradise site prevented its continuous operation from battery power supply. Specific electrical conductance, pH, dissolved oxygen concentration, and water temperature were monitored with commercially obtained battery powered electronic sensing systems. For a detailed description of the electronic systems employed, refer to the work of Woffinden and Kartchner (1968).

Because of instrument malfunction and problems relating to the adaptation of instruments for telemetry transmission, extended periods have occurred during which no valid continuous monitoring records were obtained. Reliable recordings were made, in blocks of from three to seven days in length, over a period extending from November 1967 through January 1969 at the Wellsville station. Periods of missing data occurred during the winter of 1967-68 and the summer of 1968. The Paradise continuous monitoring station was set up in April 1968, but reliable readings were obtained only during relatively short periods. Despite the difficulties sufficient data were available to allow comparisons between stations and to establish a pattern over the annual cycle using data from the Wellsville station.

Quality of data

Stream gaging was done by the USGS using rating curves and stage recorders. They felt the data provided were reliable and good and within normal tolerences.

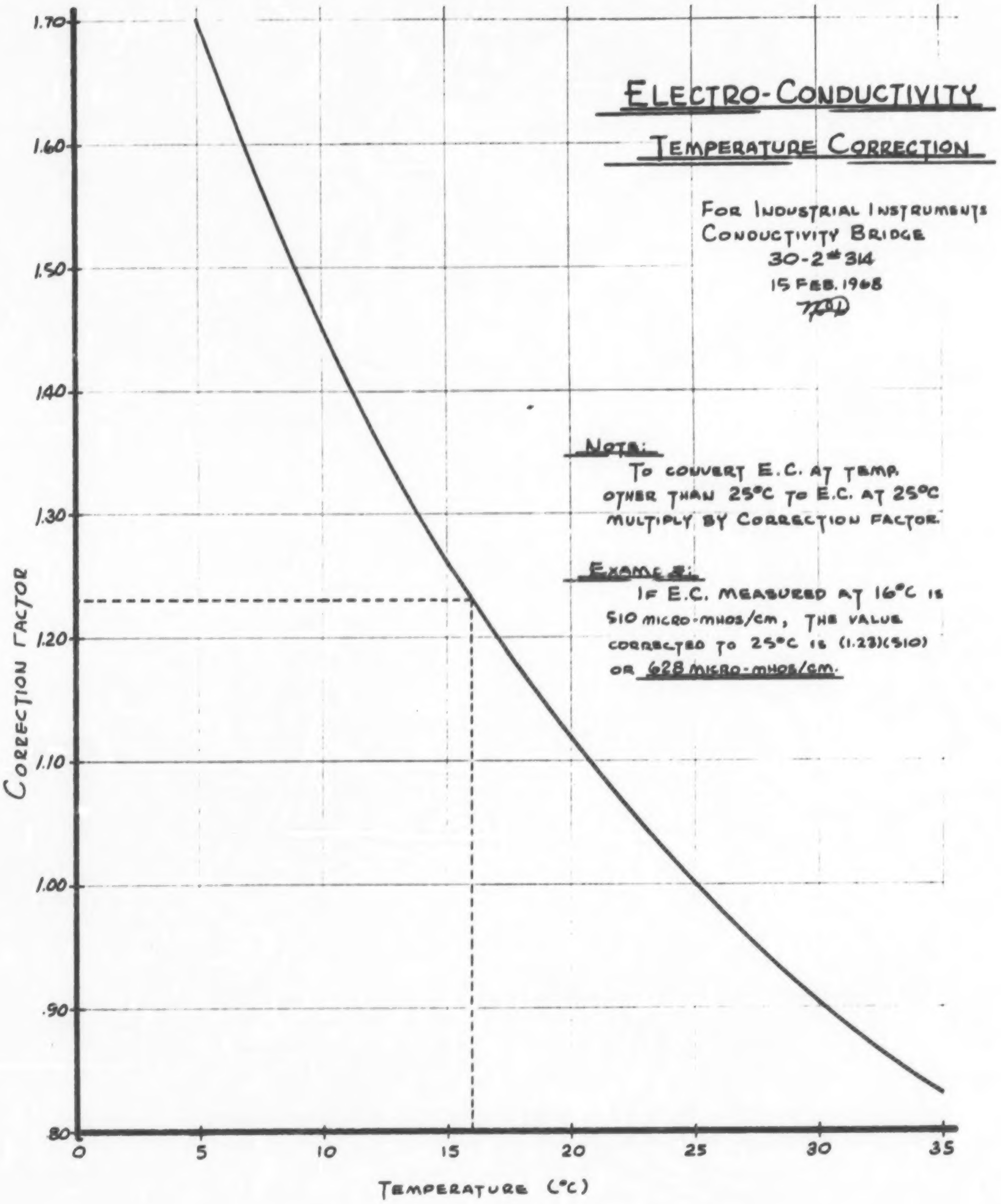
Weekly sampling data from water quality sampling were provided by both field and laboratory analyses. Field tests were pH (by colorimetric kit), dissolved oxygen (Winkler-- fixed in the field), carbon dioxide (phenothalein titration), and alkalinity (methyle orange titration); and temperature. Figure C-1, Appendix C, shows all tests conducted and summarizes all data taken for each sample. Test results reported with and (F) indicate field measurement. Laboratory tests for chemical species were

Table B-4. Groundwater sampling stations.

Station No.	Coordinates (Meters)	Description of Sampling Point	Period of Sampling
U-2311	235110	Artesian well discharging to stock watering trough about 75 yd. east of the first road east of Wellsville lower road bridge at about 200 yd. north of Highway.	101767 - 121868
U-2510	258108	Manhole for subsurface field drain about 100 yd. north of the railroad track and 100 yd. east of the Wellsville East Field Canal directly east of Greens Corner.	101767 - 121868
U-2907	294068	Spring House overflow on north side of spring house located just north of E. K. Israelsen's home on west side of highway about 1.5 miles south of Hyrum, Utah.	101767 - 121868
U-3198	312985	Seeping spring area inside curve in Forsberg Road northwest of Avon about 0.2 miles east of Little Bear River.	101767 - 121868

conducted in accordance with *Standard Methods* 1965 edition. There is no reason to suspect the quality of these data, with the exception of the specific electrical conductivity test results. The values reported for the period June 1966 to January 1968 were not corrected for temperature deviations from 25°C at the time of measurement. The room in which this measurement was taken would deviate about ±2°C from this temperature, though it was probably close to 25°C most of the time. After January 1968 all subsequent EC values are reported as EC at 25°C. The temperature calibration for the instrument used is shown in Figure B-3. Figure B-4 shows the instrument calibration against a standard sample at 25°C.

Total count and coliform counts were done by the membrane filter method. Samples were collected using a sterile bottle, which was handled in accordance with usual sterile technique.



ELECTRO-CONDUCTIVITY

TEMPERATURE CORRECTION

FOR INDUSTRIAL INSTRUMENTS
CONDUCTIVITY BRIDGE
30-2 # 314
15 FEB. 1968

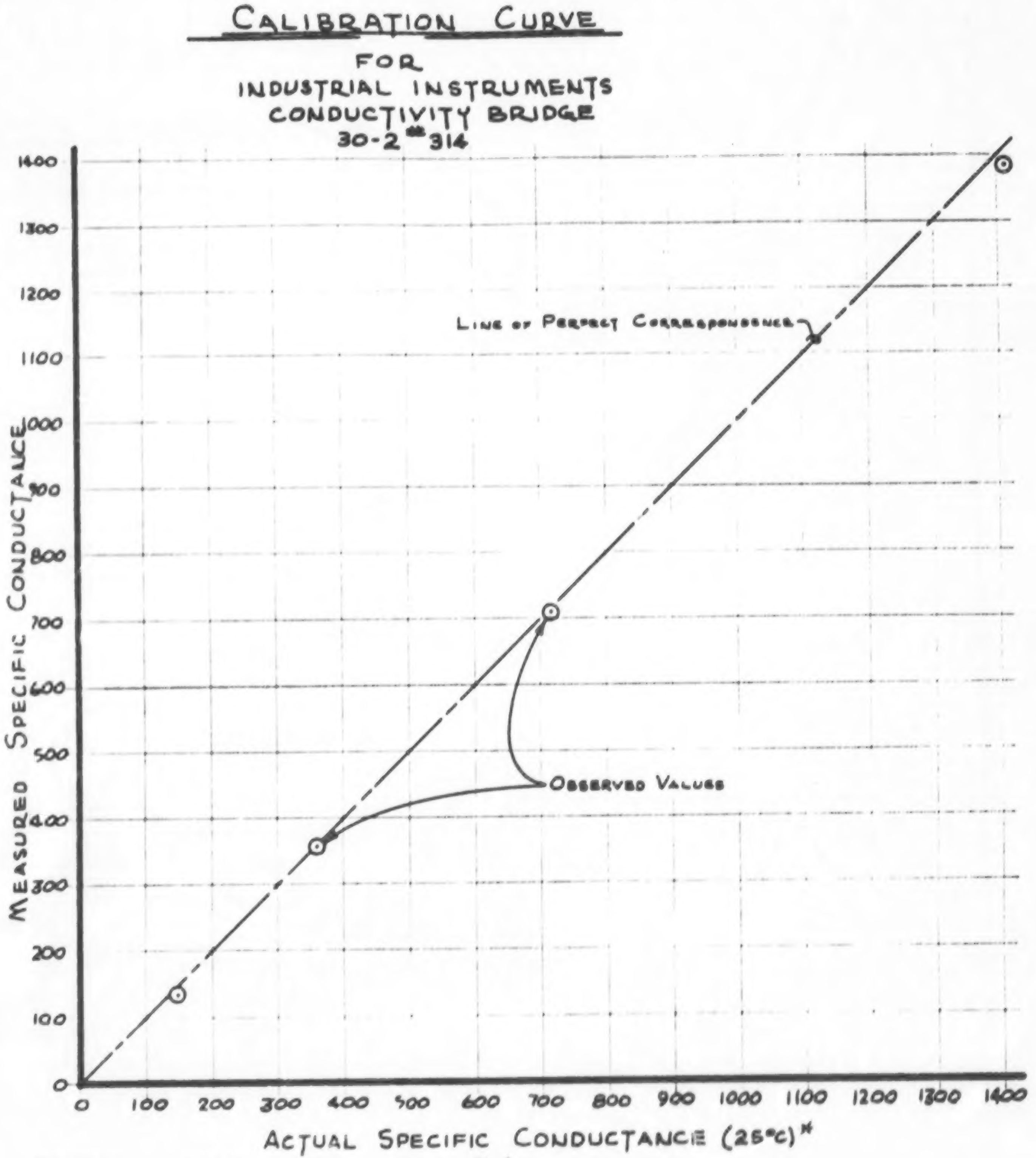
NOTE:

TO CONVERT E.C. AT TEMP. OTHER THAN 25°C TO E.C. AT 25°C MULTIPLY BY CORRECTION FACTOR.

EXAMPLE:

IF E.C. MEASURED AT 16°C IS 510 MICRO-MHOS/CM, THE VALUE CORRECTED TO 25°C IS (1.23)(510) OR 628 MICRO-MHOS/CM.

Figure B-3. Temperature correction for conductivity bridge.



SOLUTION CONC.	ACTUAL S.C.	OBS. S.C.	Δ	%Δ
0.01 m	1413	1385	-28	-1.98
.005	718	710	- 8	-1.12
.0025	360	358	- 2	-0.56
.0010	147	136	- 11	-7.50

15 FEB. 1968

* Ref. Standard Methods (12th Ed.)

Figure B-4. Conductivity bridge calibration curve for standard samples at 25°C.

APPENDIX C

WATER QUALITY DATA PROCESSING PROGRAMS

For Discrete Sample Data

Three basic utility programs were written to process weekly sampling data from 10 to 15 stations on the Little Bear River. These programs were:

(1) QULPRT—which: (a) produces an analysis summary sheet, Figure C-1, for an individual water sample; (b) calculates me/L for each anion and cation, sums total anions and total cations, and (c) calculates percent dissolved oxygen as function of temperature and elevation, as outlined in Figure C-2.

(2) SCAN—produces a list of all water quality data arranged consecutively by: (a) station for a given date, Figure C-3, and (b) chronologically by date for each station, Figure C-4.

(3) PRTPLT—produces a graphical display of desired sample data points by: (a) station for a given date, Figure C-5, or (b) chronologically by date for each station, Figure C-6. (Both plots may be produced from the same data if the data are rearranged as specified and separate runs are made.)

The first program, QULPRT, was useful in producing an orderly summary of a given sample; also several computations were done, and the output provided a means for verification of card punching. The second and third programs provided a means for visually scanning the water quality data for the Little Bear River in both time and space; this type of output was important in looking for any cyclic trends with time or in correlations between variables. Instructions for using each of these programs [1] are outlined in the following sections.

1. QULPRT

Figure C-7 is a program listing of QULPRT as programmed in Fortran V, and run on the Univac 1108. Following the program listing is a listing of input cards used by the program. The details of the input cards are described in the following section. Figure C-1 is a sample of program output.

Specific instructions

Program QULPRT requires three groups of data input cards to follow the Fortran source deck. Table C-1 specifies the exact sequence and format for each card Figure C-8 shows the deck arrangement for each of the three groups, along with the complete deck set-up for running the program.

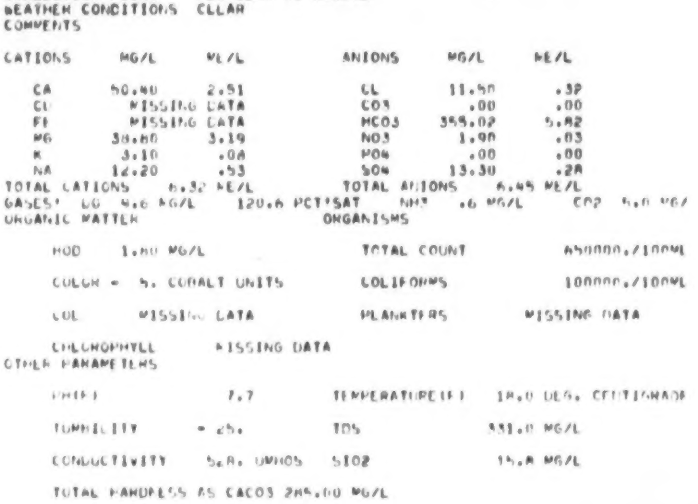
Group I consists of a single control card, containing the single variable, NSTATS, which is the number of stations for which sample data are punched. Group II contains NSTATS cards, each containing the mnemonic station identification designation, the UMT station coordinates, and the description of the station (i.e. S1276259093 Little Bear River at Salt Lake Meridian). Group III consists of NSTATS number of lots having six data cards (described above) for each lot; each lot of six represents one station.

2. SCAN

Figure C-9 is a program listing of SCAN as programmed in Fortran V and run on the Univac 1108. Following the program listing is a listing of input cards used by the program. Figures C-3 and C-4 are the two options of program output; either or both options may be specified.

Specific instructions

Program SCAN requires four groups of data input cards to follow the Fortran source deck. Table C-2 specifies the exact sequence and format for each card. Figure

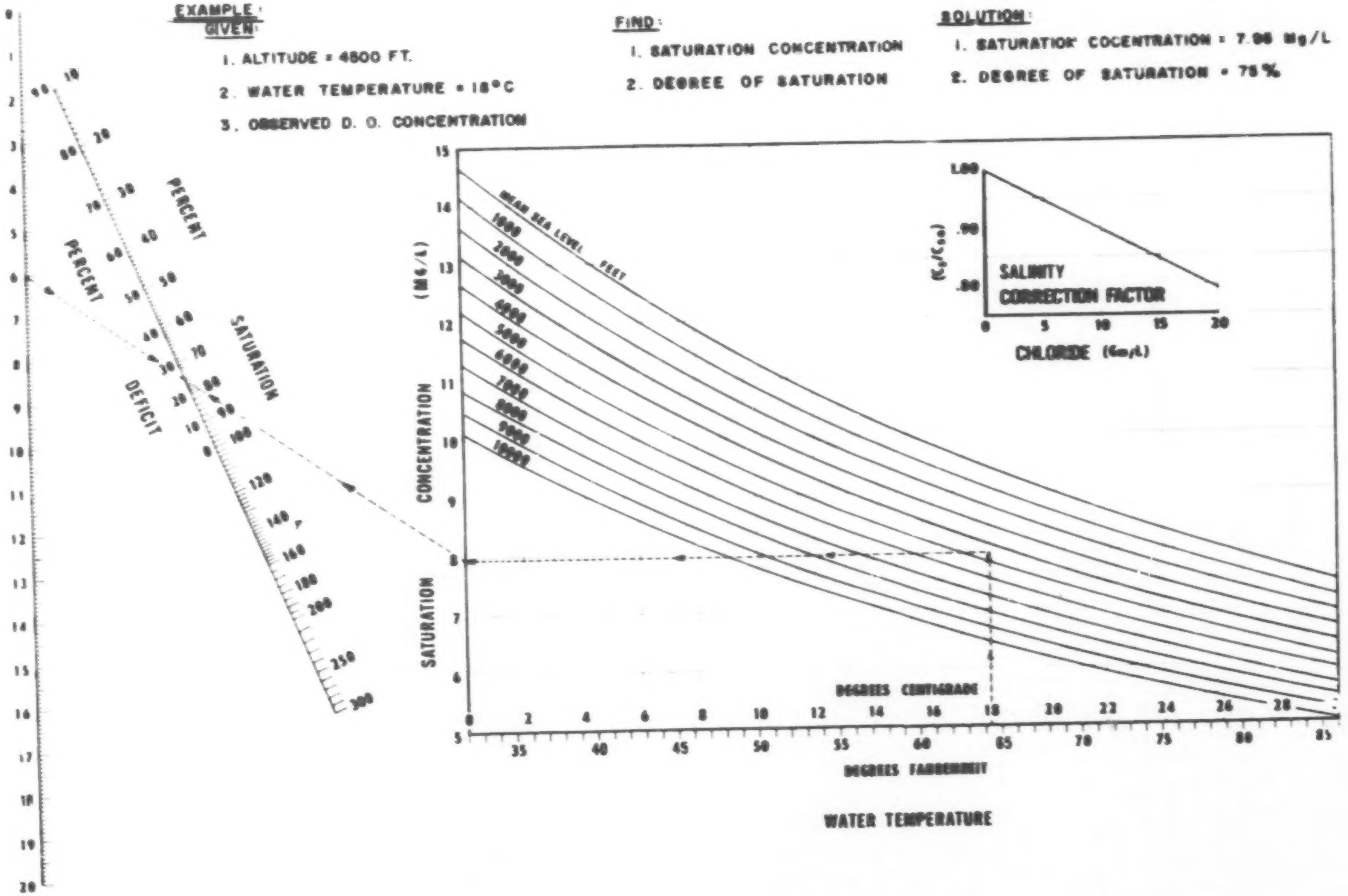


```
 S152  259093   LITTLE BEAR RIVER AT SALT LAKE MERIDIAN
STATION   S152     DATE 071367     TIME 1020     DAY OF YEAR 194
APPEARANCE          CLEAR
COLLECTION POINT    ADJACENT TO BRIDGE
WEATHER CONDITIONS  CLEAR
COMMENTS

CATIONS     MG/L      ME/L             ANIONS     MG/L      ME/L

   CA       50.40     2.51               CL       11.50      .32
   CU        MISSING DATA                CO3        .00      .00
   FE        MISSING DATA                HCO3    359.02     5.82
   MG       38.80     3.19               NO3       1.90      .03
   K         3.10      .08               PO4        .00      .00
   NA       12.20      .53               SO4      13.30      .28
TOTAL CATIONS    6.32 ME/L             TOTAL ANIONS    6.45 ME/L
GASES'  DO  9.6 MG/L    120.6 PCT'SAT    NH3   .6 MG/L     CO2  5.0 MG/
ORGANIC MATTER                        ORGANISMS

    BOD    1.80 MG/L                    TOTAL COUNT         650000./100ML

    COLOR =  5. COBALT UNITS            COLIFORMS           100000./100ML

    COD      MISSING DATA               PLANKTERS        MISSING DATA

    CHLOROPHYLL      MISSING DATA
OTHER PARAMETERS

    PH(F)              7.7         TEMPERATURE(F)   18.0 DEG. CENTIGRADE

    TURBIDITY      = 25.           TDS                331.0 MG/L

    CONDUCTIVITY    528. UMHOS   SIO2                15.8 MG/L

    TOTAL HARDNESS AS CACO3 285.00 MG/L
```

Figure C-1. Analysis summary sheet for individual water sample—sample output from QULPRT.

---

[1] Each of these programs could be improved or modified should a user so desire. For example the four weather and water quality comment cards used in QULPRT could be omitted by categorizing and number coding comments. Also the PRTPLT program has been substantially modified (by Professor Post) to add greater generality and usefulness to the program.



EXAMPLE:
GIVEN:
1. ALTITUDE = 4500 FT.
2. WATER TEMPERATURE = 18°C
3. OBSERVED D. O. CONCENTRATION

FIND:
1. SATURATION CONCENTRATION
2. DEGREE OF SATURATION

SOLUTION:
1. SATURATION COCENTRATION = 7.96 Mg/L
2. DEGREE OF SATURATION = 75%

Figure C-2. Nomograph used in QULPRT to obtain percent dissolved oxygen saturation.

C-10 shows the deck arrangement for each of the four groups, along with the program source deck and run control cards.

Group I consists of a single control card containing three variables, NSTATS, NWEEKS, and IOUT, which are described in Table C-2, Group II contains the station designation and descriptions, one for each station from which a sample was obtained, with a total of NSTATS cards in this group. Group III consists of NWEEKS/8 cards containing the data and corresponding day of the year, arranged in the sequential order in which output is desired. Group IV consists of subgroup A and subgroup B. Subgroup A contains two cards of chemical and bacteriological data for each date for the designated station (Group III cards 5 and 6 from QULPRT); these cards are arranged consecutively in order of date for a given station. Subgroup B consists of two trailer cards which are control cards for indicating that all data cards containing water quality for a given station have been read. The subgroup B trailer cards for the last station are punched differently in the last column to indicate all data have been read.

3. PRTPLT

Figure C-11 is a program listing of PRTPLT as programmed in Fortran V and run on the Univac 1108. Following the program listing is a listing of input cards used by the program. The details of the input cards are described in the following section. Program PRTPLT outputs a plot of data contained in a 54 by 120 size matrix on a 9 x 12 inch rectangular area, as shown by Figures C-5 and C-6 (reduced in size).

Two Y axis transformation options are available: one allows plotting up to 10 Y variables against a common X variable; another obtains a log transformation of any Y variable. Separate runs are required for Figures C-5 and C-6 respectively, each requiring different control card specifications and arrangement of data cards.

Specific instructions

Program PRTPLT requires two groups of data input cards to follow the Fortran source deck. Table C-3 specifies the exact sequence and format for each card. Figure C-12 shows the deck arrangement for each of the two groups, along with the deck set-up for running the program.

Group I consists of six control cards which must precede the data to be plotted. These control cards are made out in form (a) or form (b), which specifies whether the Figure C-5 type plot or the Figure C-6 type of plot will be produced; data cards must be arranged commensurately as outlined in Table C-3 and in Figure C-12.

Group II consists of three subgroups, A, B, and C. For the first station subgroups A and B are absent (actually Group I control cards replaces subgroups A and B for the first station). Subgroup A consists of a single dummy data card, which must have a zero or nine punch in column 80. If the column 80 punch is 0, then subgroup B consists of control card I-1 (but made out for the data in the subgroup C following); if this punch is 9, then subgroup C consists of control cards I-1 to I-6 (but made out for the specific manner in which the data in the subprogram C following is to be plotted). Subgroup C contains the water quality data cards (they can be cards III-5 and III-6 from Table C-1). Only ten variables may be plotted on any one plot and the selection is done by means of the format statement (see Table C-3, card I-2). The data cards are arranged in two alternate ways depending upon whether the Figure C-5 or Figure C-6 types of plots are desired; Table C-3 and Figure C-12 outline the manner of data arrangement.

```
DATA FOR THE WEEK 071367 DAY OF YEAR 194

                                     CATIONS (MG/L)                                   ANIONS (MG/L)                                OTHER PARAMETERS
STATION  DATE   TIME    CA     CU     FE     MG      K     NA     CL   HCO3    CO3    NO3    PO4    SO4   PHF   PHL   HARD      B
   S127 071367 1000   66.4 ***** *****   38.8    5.0   19.5   13.5  398.9     .0    6.7     .8   15.6   7.9   8.3  320.0   27.0
   S128 071367 1010   23.6 ***** *****   63.0    5.0   19.6    5.3  336.5     .0    1.3     .1   14.0   7.9   8.3  305.0  *****
   S152 071367 1020   50.4 ***** *****   30.8    3.1   12.2   11.5  355.0     .0    1.9     .0   13.3   7.7   8.3  285.0    3.3
   S168 071367 1040   18.0 ***** *****   36.4    1.2    5.9    9.3  209.8    7.2     .6     .0    9.0   8.4   8.4  195.0  *****
   S213 071367 1155   42.6 ***** *****   43.0    2.5   13.2   12.3  333.1     .0    3.7     .1   14.8   7.8   8.1  283.0  *****
   S246 071367 1220   33.8 ***** *****   40.3    1.8    7.6    9.5  301.3    2.4    1.7     .0    8.0   9.1   8.3  250.0  *****
   S270 071367 1330  ***** ***** ***** ***** ***** *****    7.0  ***** ***** ***** ***** *****   9.4   ***  *****   56.0
   S275 071367 1250   30.2 ***** *****   27.8     .6    7.2    9.9  212.9    6.0     .7     .0    4.5   8.4   8.5  190.0   19.0
  SEC43 071367 1350   34.8 ***** *****   19.0     .6    8.1    6.5  201.3    3.6    1.0     .0    6.7   8.1   8.4  165.0  *****
  SEC62 071367 1415   17.4 ***** *****   43.0    1.2    8.7    6.0  258.6    3.6     .0     .0    7.5   8.2   8.4  220.0   29.0
   S090 071367 1305   43.2 ***** *****   23.6     .6    8.1    5.8  237.5    4.8     .1     .0    5.7   8.4   8.5  205.0   37.0
  STF00 071367 1200   55.8 ***** *****   33.0    1.8    9.6   13.5  333.1     .0    4.0     .2   16.1   7.8   8.2  275.0  *****
   SW01 071367 0945   53.0 ***** *****   45.6    5.0   21.2   17.4  384.3     .0    6.2     .7   20.6   7.8   8.1  320.0  *****
  SLR00 071367 0850   41.0 ***** *****   21.8     .6    2.4    3.5  220.8    3.6     .3     .0    5.4   4.0   8.4  192.0  *****

                             GASES (MG/L)                      OTHER PARAMETERS (MG/L)           ORGANIC MATTER (MG/L)     ORGANISMS
STATION  DATE   TIME      DO  PCT SAT    NH3    CO2     TURB     COND     TDS    TEMP    SIO2     BOD   COLOR      TOTCNT      COLIFM
                                                             UMHOS/CM          DEG. C                            /100ML      /100ML

   S127 071367 1000      7.3    86.3     .3    5.0   -  25.     845.   425.0    15.0    19.1     1.7  -  5.   19000000.    1060000.
   S128 071367 1010      7.5    94.2     .7    3.0   -  25.     550.   301.0    19.0    15.8     1.6  -  5.    1400000.     450000.
   S152 071367 1020      9.6   120.6     .6    5.0   -  25.     528.   331.0    18.0    15.8     1.8  -  5.     550000.     100000.
   S168 071367 1040      7.6   103.3     .1     .0   -  25.     300.   211.0    22.0     4.4     1.1  -  5.      90000.       2000.
   S213 071367 1155      6.9    83.3     .3    4.0   -  25.     515.   333.0    16.0     9.1     5.9  -  5.   60000000.    6000000.
   S246 071367 1220      8.2   103.0     .6    3.0   -  25.     435.   274.0    18.0    10.7      .8  -  5.   *********   *********
   S270 071367 1330   ******   *****  ***** *****    *****     350.   *****    18.0   *****   *****    ***   *********   *********
   S275 071367 1250      9.5   119.3     .5     .0   -  25.     300.   207.0    18.0     7.8     1.6  -  5.     120000.      20000.
  SEC43 071367 1350      9.7   117.1     .7    7.0   -  25.     292.   187.0    16.0     7.7      .5  -  5.   *********   *********
  SEC62 071367 1415      8.9   111.8     .3     .0   -  25.     370.   227.0    18.0     5.0     1.5  -  5.   *********   *********
   S090 071367 1305      8.0    98.5     .1     .0   -  25.     339.   209.0    17.0     5.2      .5  -  5.     240000.      67000.
  STF00 071367 1200      6.4    86.7     .3    6.0   -  25.     519.   321.0    18.0    12.7     4.5  -  5.   18300000.    7000000.
   SW01 071367 0945      7.3    84.5     .1    5.0   -  25.     614.   449.0    14.0    21.4     4.1  -  5.    6000000.    1300000.
  SLR00 071367 0850      9.2    97.4     .3    4.0   -  25.     300.   179.0    10.0     4.0      .7  -  5.      30000.      16000.
```

Figure C-3. List of water quality data by station for a given date—sample output from SCAN.

```
STATION   5152  250093  LITTLE BEAR RIVER AT SALT LAKE MERIDIAN

                                       CATIONS (MG/L)                                       ANIONS (MG/L)                                OTHER PARAMETERS
STATION  DATE   TIME    CA      CU      FE      MG      K       NA      CL     HCO3     CO3     NO3     PO4     SO4     PHF     PHL     HARD       B
   5152 011267 1430  112.0      .0      .0    23.2     2.2     8.1    12.0   430.7    21.6     1.3      .2    11.9     8.0     8.0    280.0    46.0
   5152 011967 1145   72.0      .0      .0    32.3     2.2     9.6    12.5   275.7     8.4      .5      .1    10.6     9.2     8.3    270.0    40.0
   5152 012667 1155   60.0      .0      .0    26.8     2.2     9.6    12.5   272.1    12.0      .1      .0    11.3     8.2     8.3    260.0    51.0
   5152 020267 1600   58.8      .0      .0    25.3     1.8     9.0    13.0   257.4    13.2      .6      .0    15.3     9.4     8.4    240.0    53.0
   5152 020967 1020   56.2      .0      .0    21.8     1.5     5.9    11.3   246.4    10.8      .4      .0    11.3     9.2     8.3    230.0    44.0
   5152 021667 1000   57.8      .0      .0    23.2     1.5     9.0    12.0   245.7    14.4      .7      .0    12.2     8.2     8.1    240.0    46.0
   5152 022367 1110   51.6      .0      .0    25.8     1.5     8.1    12.0   241.6    14.4     1.0      .0    14.0     9.2     8.4    235.0    44.0
   5152 030267 1130   70.4      .0      .0    15.4     1.8     8.1    12.0   247.7    10.8      .4      .1    13.1     8.6     8.4    240.0    53.0
   5152 030967 1010   38.6      .0      .0    32.0     1.5     8.1    12.3   248.9     7.2      .4      .0    10.8     8.2     8.4    228.0    48.0
   5152 031667 1345   50.2      .0      .0    27.8     1.8     9.0    12.8   251.3     9.6      .2      .0    10.6     9.2     8.2    240.0    30.0
   5152 032967 1520   55.4      .0      .0    30.8     2.8     9.6    14.5   294.0     3.6     2.5      .2     7.3     8.0     8.2    265.0     3.3
   5152 040667 1715   48.0      .0      .0    26.4     2.8    13.8    12.3   244.0     4.8      .5      .1     8.5     8.0     8.3    230.0    92.0
   5152 041367 1800   51.4      .0      .0    22.8     1.5    10.2    12.0   258.6     1.2      .7      .1     9.6     7.8     8.3    222.0    99.0
   5152 042067 1640   24.4      .0      .0    39.8     1.8    10.8    12.5   252.5      .0      .4      .2    11.6     8.0     8.2    220.0   195.0
   5152 042767 1725   51.4      .0      .0    13.8     1.8     9.6    12.3   246.4      .0      .8      .2    10.0     8.0     8.2    210.0   163.0
   5152 050367 1730   68.8      .0      .0     8.1     1.5    19.2    12.8   241.6     7.6      .8      .1     9.8     8.2     8.3    206.0   185.0
   5152 051167 1810   27.4   *****   *****    32.0     1.2     7.4    11.0   240.7     1.2      .7      .1     9.0     8.6     8.4    200.0   440.0
   5152 051867 1725   23.8   *****   *****    33.0     1.2     7.8    10.5   228.1     1.2      .5      .1     8.3     8.0     8.4    195.0   390.0
   5152 052567 1705   44.8   *****   *****    16.0      .9     5.3     8.5   200.1     1.2     1.9      .1     9.0     8.0     8.4    177.0   654.0
   5152 060167 1125   18.2   *****   *****    27.8     1.2     5.9     6.8   201.3      .0      .8      .0     8.5     8.4     8.4    160.0   212.0
   5152 060867 1150   41.8   *****   *****    23.8     1.2     5.9     7.0   187.9     6.0      .5      .0     6.4     8.4     8.5    165.0   218.0
   5152 061567 1200    2.0   *****   *****    40.3      .9     5.9     7.0   201.3      .0      .4      .1     7.5     8.1     8.2    170.0   418.0
   5152 062267 1520   12.1   *****   *****    34.0      .9     5.3     7.5   207.4     2.4      .9      .0     8.5     8.1     8.4    170.0   256.0
   5152 062967 0950   26.2   *****   *****    37.6     2.5     9.6    10.3   270.8      .0     2.3      .1     9.8     7.9     8.2    220.0   185.0
   5152 070667 0955   39.8   *****   *****    43.3     3.1    10.8    11.0   320.9      .0     2.1      .1     9.0     7.7     8.2    265.0     3.6
   5152 071367 1020   50.4   *****   *****    38.8     3.1    12.2    11.5   355.0      .0     1.9      .0    13.3     7.7     8.3    285.0     3.3
   5152 072067 1050   65.8   *****   *****    33.3     3.5    13.8    12.1   359.4      .0     1.3      .0    14.1     7.6     8.0    300.0     5.0
   5152 072767 1010   71.8   *****   *****    32.0     5.0    17.2     8.5   395.1      .0     2.6      .0    13.1     7.4     7.5    310.0     3.4
   5152 080367 1000   62.4   *****   *****    38.8     3.1    11.5    12.5   389.2      .0     1.9      .0    11.3     7.8     7.8    315.0     1.3
   5152 080967 1510   69.2   *****   *****    23.6     3.1     5.7    12.2   322.1      .0      .5      .0    12.2     7.8     8.1    270.0     1.4
   5152 081767 0945   70.2   *****   *****    27.8     3.8     6.3    12.5   355.9      .0     1.0      .1    12.8     7.6     8.6    290.0      .9
   5152 082367 0930   39.7   *****   *****    46.4     3.1     9.6    12.5   341.6      .0     1.0      .5    10.8     7.6     8.1    290.0     3.2
   5152 082967 0930   61.2   *****   *****    23.6     2.5    13.5    18.0   313.5      .0     1.5      .3    11.9     8.4     8.2    250.0     9.9
   5152 090667 0950   63.4   *****   *****    32.0     3.1    10.7     3.5   389.2      .0     1.0      .1    12.8     7.6     8.2    290.0     3.8
   5152 091367 0935   58.4   *****   *****    31.4     3.1     9.6    12.0   341.6      .0      .6      .1    10.3     ***     7.5    275.0     5.0
   5152 092067 1000   54.7   *****   *****    33.0     3.1     9.6    13.0   341.6      .0      .5      .1     9.0     7.6     8.0    285.0     3.2
   5152 100667 1005   56.8   *****   *****    33.5     3.1     9.0    13.5   330.6     3.6      .6      .0    11.9     7.7     8.3    280.0     3.8
   5152 101067 1200   55.4   *****   *****    32.3     2.2     7.4    11.5   312.7      .0     1.3      .2    11.0     7.8     8.2    270.0    10.0
   5152 101767 1000    3.8   *****   *****    57.3     2.2     7.4    14.5   287.9     1.2     1.1      .2    12.8     9.6     8.5    245.0    73.0
   5152 102467 1015   50.2   *****   *****    27.8     2.2     8.3    12.0   281.8     9.6      .8      .0    11.9     9.2     8.5    240.0    71.0
   5152 110167 1020   77.4   *****   *****    44.2     2.2     7.4    11.5   292.4     2.4      .6      .5     9.7     9.7     8.4    250.0    67.0
   5152 110867 1100   52.2   *****   *****    27.8     2.2     8.1    12.5   264.7     9.6     1.0      .1     9.3     8.2     8.4    245.0    66.0
   5152 111467 1100   73.0   *****   *****    45.6     2.2     7.3    13.3   272.1     9.6      .8      .1     8.3     8.1     8.4    245.0    55.0
   5152 112067 1110   15.5   *****   *****    51.4     1.8     8.1    16.0   240.4      .0     1.2      .1     9.8     6.4     8.4    250.0    56.0
   5152 112867 1020   48.4   *****   *****    51.4     1.8     7.5    16.0   281.9     3.6     1.3      .1     8.8     7.9     8.4    250.0    54.0
   5152 120567 1040   11.5   *****   *****    51.4     2.2     9.3    12.5   268.4     9.6     2.3      .1    10.0     ***     8.4    240.0    58.0
   5152 121367 1045   26.4   *****   *****    42.4     2.2     7.8    10.5   268.4     9.6     1.5      .1     7.5     ***     8.4    240.0    56.0
```

```
STATION   5152  250093  LITTLE BEAR RIVER AT SALT LAKE MERIDIAN

                                 GASES (MG/L)                       OTHER PARAMETERS (MG/L)                ORGANIC MATTER (MG/L)     ORGANISMS
STATION  DATE   TIME       DO    PCT SAT    NH3      CO2      TURB     COND     TDS     TEMP     SIO2      BOD     COLOR       TOTCNT      COLIFM
                                                                     UMHOS/CM          DEG. C                                 /100ML      /100ML
   5152 011267 1430      14.7    134.3      .1       .0   -   25.     458.   275.0      4.0      8.2      2.9     -   5.      26000.      31000.
   5152 011967 1145      14.1    125.0      .0       .0   -   25.     452.   287.0      3.0     14.0      1.7     0   5.     300000.      43000.
   5152 012667 1155      12.8    119.4      .4       .0   -   25.     475.   200.0      5.0     17.5      3.2     0   5.      50000.       1000.
   5152 020267 1600      10.0     97.6      .3       .0   -   25.     408.   243.0      5.0     11.1      4.0     0   5.   *********   *********
   5152 020967 1020      13.0    125.7      .2       .0   -   25.     412.   234.0      4.0     11.5      4.5     0   5.     300000.     106000.
   5152 021667 1000      11.0    105.7      .0       .0   -   25.     395.   260.0      4.0     11.0      4.0     0   5.     160000.       1000.
   5152 022367 1110      10.3     98.4      .3       .0   -   25.     430.   284.0      5.0     10.4      1.9     -   5.       4000.       1000.
   5152 030267 1130      12.8    123.3      .3       .0   -   25.     394.   257.0      6.0     10.4      3.7     -   5.     360000.       1000.
   5152 030967 1010      10.6    101.4      .0       .0   -   25.     377.   268.0      8.0     10.5    *****     0   5.   *********   *********
   5152 031667 1345       9.6     92.2      .2       .0   -   25.     395.   283.0      8.0     12.1      4.2     -   5.      52000.       3000.
   5152 032967 1520      10.8    101.1      .0       .0   -   25.     493.   312.0      5.0     20.2      4.0     -   5.   *********   *********
   5152 040667 1715      10.7    104.0      .5       .0   -   25.     432.   248.0      8.0     12.1      3.1     -   5.     320000.      18000.
   5152 041367 1800      10.5    106.0      .0       .0   -   25.     420.   284.0      8.0     12.0    *****     -   5.      70000.       5000.
   5152 042067 1640      11.2    113.1      .0      5.0   -   25.     362.   231.0      8.0     10.5      5.8     -   5.     100000.       4000.
   5152 042767 1725       9.7    100.4      .0      7.0   -   25.     390.   214.0      9.0     13.2      2.4     -   5.     123000.       1000.
   5152 050367 1730      10.0    105.9      .0       .0   -   25.     374.   263.0     13.0     17.1      2.4     -   5.   *********   *********
   5152 051167 1810      10.2    105.5      .6       .0       26.     352.   219.0      9.0     11.3      2.2     -   5.     420000.       1000.
   5152 051867 1725      10.0    110.8      .0       .0   -   25.     353.   227.0     12.0     13.6      2.6     -   5.      30000.       1000.
   5152 052567 1705       9.8    110.0      .0       .0       63.     310.   189.0     14.0     10.7      2.3     -   5.     430000.       1000.
   5152 060167 1125       9.1    105.1      .1       .0   -   25.     281.   216.0     14.0      9.1      2.7     -   5.      70000.       4000.
   5152 060867 1150       9.4    113.5      .5       .0     *****     298.   190.0     16.0      8.2      2.8     -   5.      90000.      12000.
   5152 061567 1200       8.6     99.4      .6       .0     *****     302.   173.0     14.0      8.4      2.2     -   5.      70000.      12000.
   5152 062267 1520       8.0     96.6      .5       .0     *****     315.   178.0     16.0      4.6      2.3     -   5.   *********   *********
   5152 062967 0950       9.8    118.1      .4      5.0     *****     438.   215.0     19.0     10.5       .2     -   5.     210000.      54000.
   5152 070667 0955       7.3     88.1      .1      3.0     *****     478.   286.0     16.0     14.0      1.8     -   5.     800000.     136000.
   5152 071367 1020       9.4    120.6      .6      9.0   -   25.     528.   331.0     19.0     15.9      1.8     -   5.     650000.     106000.
   5152 072067 1050       9.3    118.5      .1      9.0   -   25.     582.   351.0     17.0     14.5      1.0     -   5.    2400000.     180000.
   5152 072767 1010       8.2    101.0      .1      8.0   -   25.     582.   376.0     17.0     15.4      1.5     -   5.   10300000.    2620000.
   5152 080367 1000       7.6      7.6      .2     17.0   -   25.     537.   364.0    *****     15.8      1.6     -   5.      57000.     190000.
   5152 080967 1510    ******    *****      .4      6.0   -   25.     513.   315.0     29.0     17.1      5.6         5.   *********   *********
   5152 081767 0945       7.0     86.2      .7      6.0   -   25.     515.   335.0     17.0     16.8       .2     -   5.   *********   *********
   5152 082367 0930       6.4     82.1      .0      7.0   -   25.     470.   335.0     16.0     16.7       .6     -   5.     630000.      80000.
   5152 082967 0930       5.4     66.5      .2      5.0       91.     450.   349.0     17.0     12.1      1.3     -   5.     380000.     110000.
   5152 090667 0950       6.6     81.3      .5      6.0   -   25.     535.   327.0     17.0     17.1      1.4     -   5.    2000000.     310000.
   5152 091367 0935       8.0      8.0      .3      5.0   -   25.     408.   270.0    *****     16.8      1.3     -   5.      90000.      50000.
   5152 092067 1000       7.6     86.1      .4      4.0   -   25.     429.   330.0     13.0     18.3       .8     -   5.     110000.      16000.
   5152 100667 1005       7.5     87.1      .3      9.0   -   25.     490.   320.0     12.0     19.1      2.1     -   5.    4100000.     770000.
   5152 101067 1200       8.9    103.0      .3      8.0   -   25.     450.   285.0     14.0     22.5      2.5     -   5.   *********   *********
   5152 101767 1000       7.8     86.5      .3       .0   -   25.     440.   271.0     12.0     16.0      6.4     -   5.    3500000.      15000.
   5152 102467 1015       8.6     93.2      .0       .0   -   25.     395.   280.0     11.0     12.0      2.8     -   5.       2000.       1000.
   5152 110167 1020      10.5    111.2     1.1       .0   -   25.     440.   273.0     10.0     12.3      2.0     -   5.       1200.       6000.
   5152 110867 1100      12.6    130.4      .2       .0   -   25.     450.   259.0      9.0     10.4      2.3     -   5.      14000.       1000.
   5152 111467 1100      11.9    123.1      .4       .0   -   25.     450.   285.0      9.0     10.2      2.2     -   5.   *********   *********
   5152 112067 1110      12.0    121.7      .0       .0   -   25.     450.   288.0      8.0     10.5      2.7     -   5.     340000.      11000.
   5152 112867 1020      11.2    137.6      .2       .0   -   25.     420.   259.0      6.0     10.6      2.3     -   5.      40000.        200.
   5152 120567 1040      12.3    117.6      .2       .0   -   25.     400.   273.0      4.5     13.8      2.9     -   5.      34000.        100.
   5152 121367 1045    ******    *****      .3    *****   -   25.     442.   257.0      2.0     11.6      3.9     -   5.      21000.        800.
```

Figure C-4 List of water quality data by date for a given station—sample output from SCAN.

```
MULTIPLE PLOT DATA FOR DATE 071367.  X AXIS  DISTANCE ONE INCH = 1.7 MILES.  NOBS =   19

VARIABLE        COND        TDS      PH(F)      FLOW
PLOT CHAR         C           S        P          0
ORIGIN 125          0.          0.        .0         .0
UNITS/INCH     100         100          1         10
NO MISSING        0           1         0          6
  S127 125        645.        425.       7.9       27.0
  S124 128        550.        381.       7.9      *****
  S152 152        528.        331.       7.7        3.3
  S168 168        300.        211.       8.4      *****
  S213 213        515.        330.       7.8      *****
  S246 246        435.        274.       8.1      *****
  S270 270        330.        ****       8.4       56.0
  S275 275        300.        200.       8.4       19.0
 SCC43 298        292.        187.       8.1      *****
 SCC52 317        370.        227.       8.2       29.0
  SOCC 276        339.        209.       8.4       37.0
 STFCC 215        519.        321.       7.8      *****
  SWG1 127        618.        449.       7.8      *****
 SLRGC 999        300.        179.       8.0      *****
```

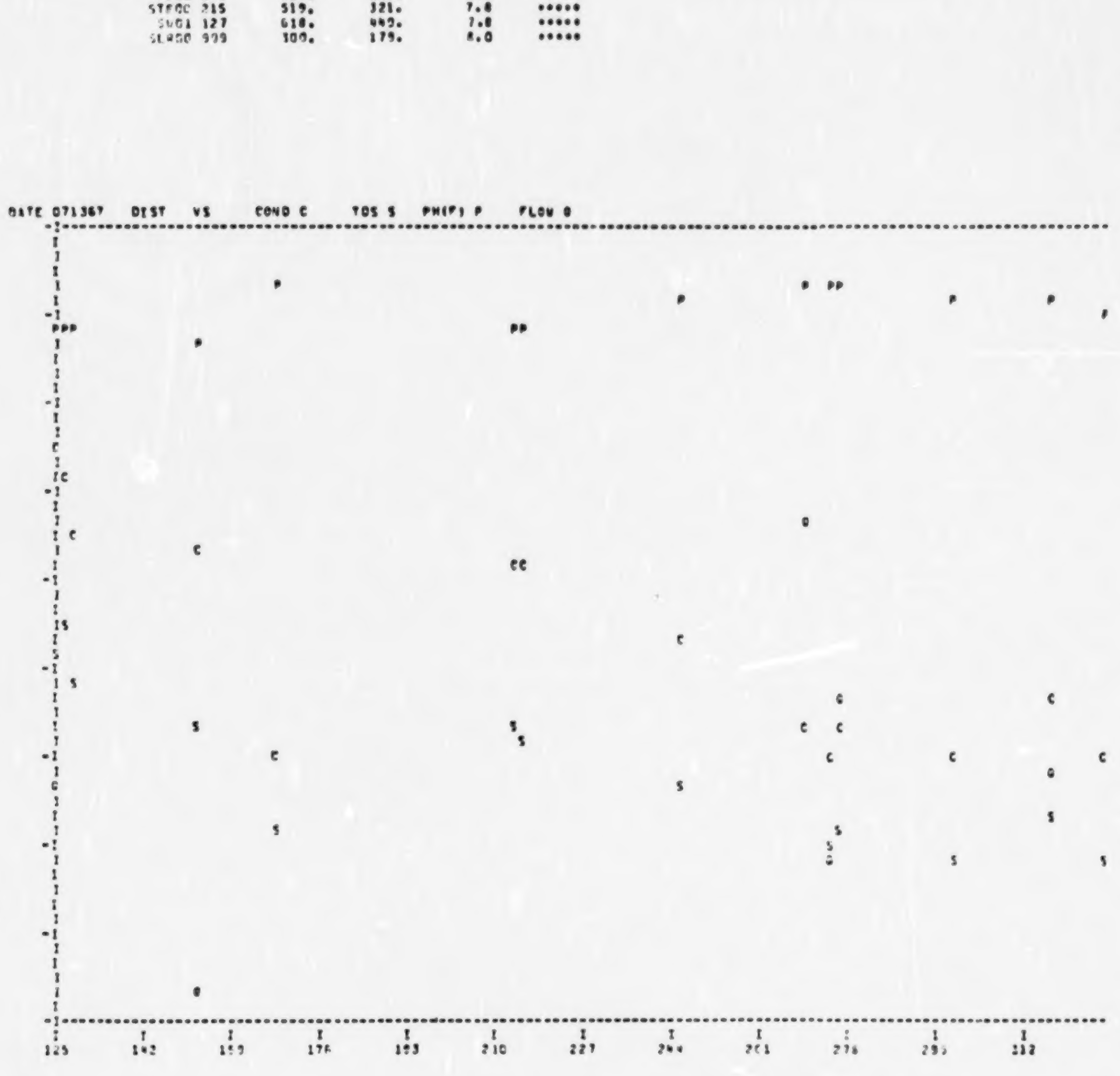


Figure C-5. Graphical display of water quality data by station for a given date–sample output from PRTPLT.

```
MULTIPLE PLOT DATA FOR STATION   5152.  YEAR 1967. TIME ONE INCH = 30.0 DAYS.  NOBS =   47

VARIABLE        COND        TDS       PHIFI       FLOW
PLOT CHAR        C           S          P          Q
ORIGIN    0        0.          0.        .0          .0
UNITS/INCH     100         100          1         80
NO MISSING       0           0          3          0
011267  12      459.        275.        8.0       80.0
011967  19      457.        287.        8.2       80.0
012667  26      477.        280.        8.2       51.0
020267  33      403.        283.        8.4       53.0
020967  40      412.        258.        8.2       44.0
021667  47      395.        260.        8.2       46.0
022367  54      430.        294.        8.2       44.0
030267  61      334.        257.        8.6       53.0
030967  68      377.        264.        8.2       48.0
031667  75      395.        240.        8.2       30.0
032967  88      499.        312.        8.7        3.3
040667  96      432.        248.        8.0       92.0
041367 103      420.        254.        7.7       99.0
042067 110      362.        236.        8.0      135.0
042767 117      390.        218.        8.0      153.0
050367 123      369.        263.        8.2      195.0
051167 131      352.        213.        8.6      440.0
051867 138      363.        227.        8.0      390.0
052567 145      310.        194.        8.0      654.0
060167 152      281.        214.        8.4      212.0
060867 159      288.        195.        8.4      214.0
061567 166      302.        173.        8.1      418.0
062267 173      315.        174.        8.1      296.0
062967 180      438.        255.        7.9      195.0
070667 187      479.        296.        7.7        3.4
071367 194      528.        331.        7.7        3.3
072067 201      582.        351.        7.6        5.0
072767 208      563.        376.        7.8        3.4
080367 215      577.        364.        7.9        1.3
080967 221      513.        315.        7.8        1.4
081767 229      515.        335.        7.6         .4
082367 235      477.        335.        7.8        3.2
082967 241      450.        302.        8.4        4.4
090667 249      535.        327.        7.6        3.8
091367 256      448.        271.       ****        5.0
092067 263      425.        280.        7.6        3.2
100467 277      450.        281.        7.7        3.0
101067 283      455.        285.        7.9       10.0
101767 290      440.        271.        8.0       73.0
102467 297      395.        210.        8.2       71.0
110167 305      440.        273.        8.7       57.0
110867 312      440.        253.        8.2       56.0
111467 318      450.        262.        8.1       55.0
112067 324      450.        281.        8.4       56.0
112867 332      470.        254.        7.9       54.0
120467 338      440.        273.       ****       58.0
121367 347      443.        257.       ****       56.0
```

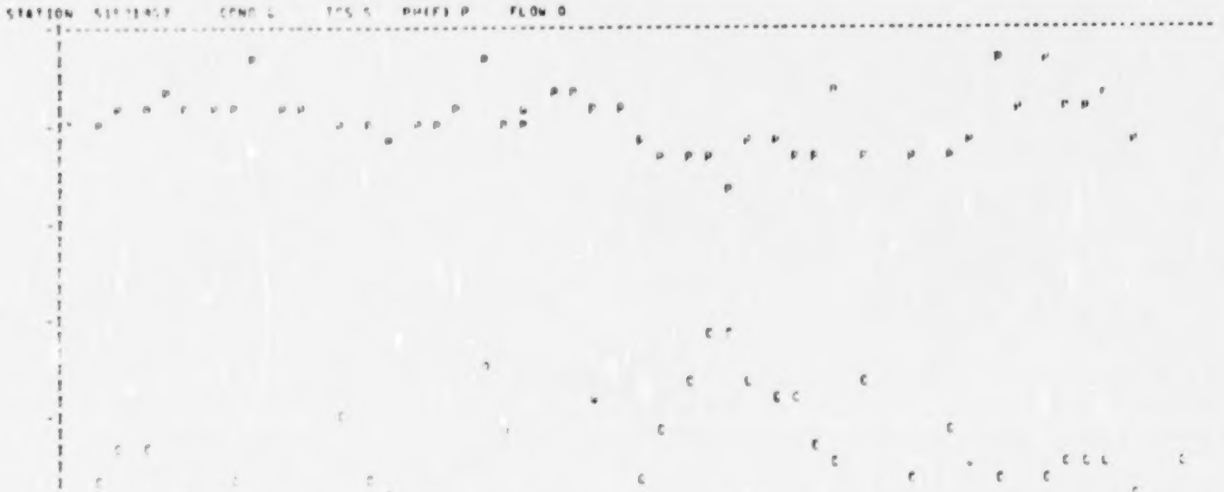
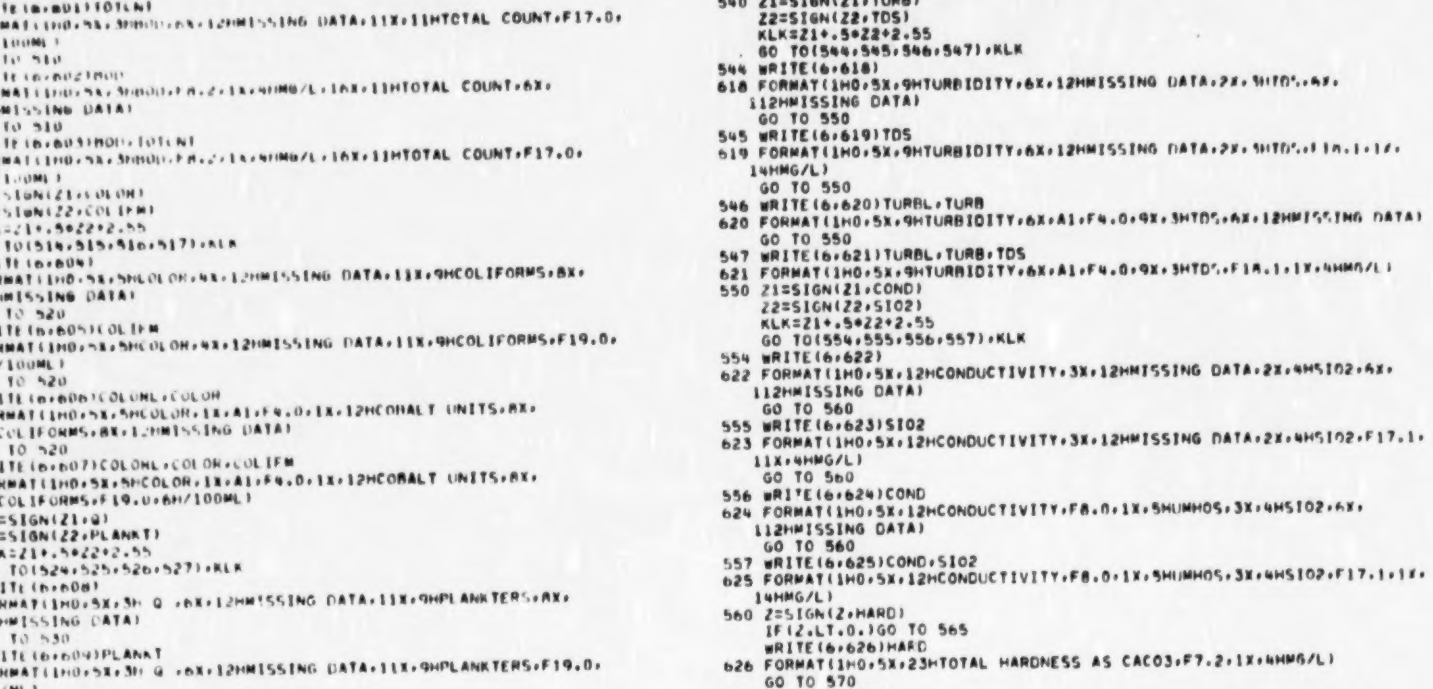


Figure C-6. Graphical display of water quality data by date for a given station—sample output from PRTPLT.

```
*I FOR QULPRT,QULPRT
C   C  QUALITY DATA PRINTOUT AND VERIFICATION
      DIMENSION APPEAR(15),COLL(15),WCOND(15),CMNTS(15)
      REAL K,MG,NA,NO3,NH3,MG1,K1,NA1,NO31
      INTEGER NAME(18,31),KTR(31),LL(31),ST1
      READ(5,99)NSTATS,BK
   99 FORMAT(I5,A6)
      N=NSTATS+1
      DO 2 J=1,18
    2 NAME(J,N)=BK
      Z=1.
      Z1=1.
      Z2=1.
      Z3=1.
      DO 300 I=1,NSTATS
  300 READ(5,100) (NAME(J,I), J=1,18)
  100 FORMAT(A6, 2X, A6, 16A4)
    1 READ(5,101)ST1, DATE,TIME,APPEAR, L
  101 FORMAT(A6, 2X, A6,2X,I4, 14A4,A3,I1)
      IF(L.NE.1) GO TO 80
      READ(5,102) COLL,L
  102 FORMAT(20X,14A4,A3,I1)
      IF(L.NE.2)GO TO 60
      READ(5,102) WCOND,L
      IF(L.NE.3) GO TO 80
      READ(5,102) CMNTS, L
      IF(L.NE.4) GO TO 80
      READ(5,103)JULDAY,CA,CU,FE,MG,K,NA,CL,B,A,NO3,PO4,SO4,PHF,Q,L
  103 FORMAT(13XI3,4X13F4.1,F6.1,1XI1)
      IF(L.NE.5) GO TO 80
      READ(5,104)DO,NH3,CO2,PHH,TURBL,TURB,COND,TDS,T,HARD,SIO2,BOD,
     1COLOHL,COLOR,TOTCNT,COLIFM,PLANKT,L
  104 FORMAT(16X4F4.1,A1,F3.0,F4.0,2F4.1,F4.0,2F4.1,A1,F3.0,3F5.0,I1)
      IF(L.NE.6)GO TO 80
      DO 5 I=1,NSTATS
      IF(NAME(1,I).EQ.ST1)GO TO 10
    5 CONTINUE
      I=NSTATS+1
      NAME(1,I)=ST1
   10 WRITE(6,200)(NAME(J,I),J=1,18)
  200 FORMAT(1H1, A6, 2X, A6, 2X, 16A4)
      WRITE(6,201) ST1, DATE,TIME, JULDAY
  201 FORMAT(9H STATION A6,5X5HDATE ,A6,5X4HTIME,I5,5X11HDAY OF YEAR,I4)
      WRITE(6,202) APPEAR
  202 FORMAT(11H APPEARANCE, 9X,14A4,A3)
      WRITE(6,203) COLL
  203 FORMAT(17H COLLECTION POINT, 3X, 14A4,A3)
      WRITE(6,204)WCOND
  204 FORMAT(19H WEATHER CONDITIONS, 1X, 14A4, A3)
      WRITE(6,205)CMNTS
  205 FORMAT(9H COMMENTS, 11X, 14A4, A3)
      WRITE(6,206)
  206 FORMAT(8H0CATIONS5X4HMG/L5X4HME/L10X6HANIONS5X4HMG/L5X4HME/L)
      DO 15 I=1,31
   15 KTR(I)=1
      SC=0
      SA=0
      Z=SIGN(Z,CA)
      IF(Z.LT.0.)GO TO 20
      CA1=CA*.04990
      SC=SC+CA1
      KTR(1)=0
   20 Z=SIGN(Z,CU)
      IF(Z.LT.0.)GO TO 21
      CU1=CU*.03148
      SC=SC+CU1
      KTR(2)=0
   21 Z=SIGN(Z,FE)
      IF(Z.LT.0.)GO TO 22
      FE1=FE*.05372
      SC=SC+FE1
      KTR(3)=0
   22 Z=SIGN(Z,MG)
      IF(Z.LT.0.)GO TO 23
      MG1=MG*.08226
      SC=SC+MG1
      KTR(4)=0
   23 Z=SIGN(Z,K)
      IF(Z.LT.0.)GO TO 24
      K1=K*.02557
      SC=SC+K1
      KTR(5)=0
   24 Z=SIGN(Z,NA)
      IF(Z.LT.0.)GO TO 25
      NA1=NA*.04350
      SC=SC+NA1
      KTR(6)=0
   25 Z=SIGN(Z,CL)
      IF(Z.LT.0.)GO TO 26
      CL1=CL*.02821
      SA=SA+CL1
      KTR(7)=0
   26 Z=SIGN(Z,A)
      IF(Z.LT.0.)GO TO 27
      CO3=12.*A
      CO31=CO3*.03333
      SA=SA+CO31
      KTR(8)=0
   27 Z=SIGN(Z,B)
      IF(Z.LT.0.)GO TO 28
      HCO3=12.2*(B-2.*A)
      HCO31=.01639*HCO3
      SA=SA+HCO31
      KTR(9)=0
   28 Z=SIGN(Z,NO3)
      IF(Z.LT.0.)GO TO 29
      NO31=.01613*NO3
      SA=SA+NO31
      KTR(10)=0
   29 Z=SIGN(Z,PO4)
      IF(Z.LT.0.)GO TO 30
      PO41=PO4*.03159
      SA=SA+PO41
      KTR(11)=0
   30 Z=SIGN(Z,SO4)
      IF(Z.LT.0.)GO TO 31
      SO41=SO4*.02083
      SA=SA+SO41
      KTR(12)=0
   31 DO 35 I=1,6
   35 LL(I)=KTR(I)*2+KTR(I+6)*1+1
      LL1=LL(1)
      GO TO (36,37,38,39),LL1
   36 WRITE(6,207) CA, CA1, CL, CL1
  207 FORMAT(1H0,3X,2HCA,F11.2,F9.2,12X,2HCL,F12.2,F9.2)
      GO TO 152
   37 WRITE(6,208)CA, CA1
  208 FORMAT(1H0,3X,2HCA,F11.2,F9.2,12X,2HCL,8X,12HMISSING DATA)
      GO TO 152
   38 WRITE(6,209) CL, CL1
  209 FORMAT(1H0,3X,2HCA,8X,12HMISSING DATA,12X,2HCL,F12.2,F9.2)
      GO TO 152
   39 WRITE(6,210)
  210 FORMAT(1H0, 3X, 2HCA, 8X, 12HMISSING DATA, 12X, 2HCL, 8X,
     112HMISSING DATA)
  152 LL2=LL(2)
      GO TO (40,41,42,43),LL2
   40 WRITE(6,211)CU,CU1,CO3, CO31
  211 FORMAT(1H ,3X,2HCU,F11.2,F9.2,12X,3HCO3,F11.2,F9.2)
      GO TO 153
   41 WRITE(6,212)CU,CU1
  212 FORMAT(1H ,3X,2HCU,F11.2,F9.2,12X,3HCO3,7X,12HMISSING DATA)
      GO TO 153
   42 WRITE(6,213)CO3,CO31
  213 FORMAT(1H ,3X,2HCU,8X,12HMISSING DATA,12X,3HCO3,F11.2,F9.2)
      GO TO 153
   43 WRITE(6,214)
  214 FORMAT(1H ,3X,2HCU,8X,12HMISSING DATA,12X,3HCO3,7X,
     112HMISSING DATA)
  153 LL3=LL(3)
      GO TO(44,45,46,47),LL3
   44 WRITE(6,215)FE,FE1,HCO3,HCO31
  215 FORMAT(1H ,3X,2HFE,F11.2,F9.2,12X,4HHCO3,F10.2,F9.2)
      GO TO 154
   45 WRITE(6,216)FE,FE1
  216 FORMAT(1H ,3X,2HFE,F11.2,F9.2,12X,4HHCO3,6X,12HMISSING DATA)
      GO TO 154
   46 WRITE(6,217)HCO3,HCO31
  217 FORMAT(1H ,3X,2HFE,8X,12HMISSING DATA,12X,4HHCO3,F10.2,F9.2)
      GO TO 154
   47 WRITE(6,218)
  218 FORMAT(1H ,3X,2HFE,8X,12HMISSING DATA,12X,4HHCO3,6X,
     112HMISSING DATA)
  154 LL4=LL(4)
      GO TO(48,49,50,51),LL4
   48 WRITE(6,219)MG,MG1,NO3,NO31
  219 FORMAT(1H ,3X,2HMG,F11.2,F9.2,12X,3HNO3,F11.2,F9.2)
      GO TO 155
   49 WRITE(6,220)MG,MG1
  220 FORMAT(1H ,3X,2HMG,F11.2,F9.2,12X,3HNO3,7X,12HMISSING DATA)
      GO TO 155
   50 WRITE(6,221)NO3,NO31
  221 FORMAT(1H ,3X,2HMG,8X,12HMISSING DATA,12X,3HNO3,F11.2,F9.2)
      GO TO 155
   51 WRITE(6,222)
  222 FORMAT(1H ,3X,2HMG,8X,12HMISSING DATA,12X,3HNO3,7X,
     112HMISSING DATA)
  155 LL5=LL(5)
      GO TO(52,53,54,55),LL5
   52 WRITE(6,223)K,K1,PO4,PO41
  223 FORMAT(1H ,3X,1HK,F12.2,F9.2,12X,3HPO4,F11.2,F9.2)
      GO TO 156
   53 WRITE(6,224)K,K1
  224 FORMAT(1H ,3X,1HK,F11.2,F9.2,13X,3HPO4,7X,12HMISSING DATA)
      GO TO 156
   54 WRITE(6,225)PO4,PO41
  225 FORMAT(1H ,3X,1HK,9X,12HMISSING DATA,12X,3HPO4,F11.2,F9.2)
      GO TO 156
   55 WRITE(6,226)
  226 FORMAT(1H ,3X,1HK,9X,12HMISSING DATA,12X,3HPO4,7X,
     112HMISSING DATA)
  156 LL6=LL(6)
      GO TO(56,57,58,59),LL6
   56 WRITE(6,227)NA,NA1,SO4,SO41
  227 FORMAT(1H ,3X,2HNA,F11.2,F9.2,12X,3HSO4,F11.2,F9.2)
      GO TO 157
   57 WRITE(6,228)NA,NA1
  228 FORMAT(1H ,3X,2HNA,F11.2,F9.2,12X,3HSO4,7X,12HMISSING DATA)
      GO TO 157
   58 WRITE(6,229)SO4,SO41
  229 FORMAT(1H ,3X,2HNA,8X,12HMISSING DATA,12X,3HSO4,F11.2,F9.2)
      GO TO 157
   59 WRITE(6,230)
  230 FORMAT(1H ,3X,2HNA,8X,12HMISSING DATA,12X,3HSO4,7X,
     112HMISSING DATA)
  157 WRITE(6,250) SC, SA
  250 FORMAT(1H3,13HTOTAL CATIONS,F8.2,1X,4HME/L,9X,12HTOTAL ANIONS,
     1F8.2,1X,4HME/L)
       DO1=1000.0/(81.3+(2.462*T))
       DO1=(DO/DO1)*100.0
       Z1=SIGN(Z1,DO)
       Z2=SIGN(Z2,NH3)
       Z3=SIGN(Z3,CO2)
       KLK=Z1+Z1+Z2+.5*Z3+4.55
       GO TO (490,491,496,492,495,497,494,493),KLK
  490 WRITE(6,470)
  470 FORMAT(1H3,6HGASES ,2X,12HDO   NH3   CO2,2X,12HMISSING DATA)
      GO TO 503
  491 WRITE(6,471)CO2
  471 FORMAT(1H3,6HGASES ,2X,7HDO   NH3,2X,12HMISSING DATA,5X,3HCO2,F6.1,
     11X,4HMG/L)
      GO TO 503
  492 WRITE(6,472)NH3,CO2
  472 FORMAT(1H3,6HGASES ,2X,2HDO,1X,12HMISSING DATA,2X,3HNH3,F6.1,1X,
     14HMG/L,5X,3HCO2,F6.1,1X,4HMG/L)
      GO TO 503
  493 WRITE(6,473)DO,DO1,NH3,CO2
  473 FORMAT(1H3,6HGASES ,2X,2HDO,F5.1,1X,4HMG/L,F9.1,1X,7HPCT SAT,4X,
```

Figure C-7. Program listing of QULPRT—and input data set-up for run.

```
   13HNH3,F5.1,1X,4HMG/L,5X,3HCO2,F5.1,1X,4HMG/L)
    GO TO 503
496 WRITE(6,476)DO,DO1,NH3
476 FORMAT(1H3,6HBASES ,2X,2HDO,F5.1,1X,4HMG/L,F7.2,1X,7HPCT SAT,6X,
   13HNH3,F5.1,1X,4HMG/L,2X,3HCO2,1X,12HMISSING DATA)
    GO TO 503
495 WRITE(6,475)DO,DO1
475 FORMAT(1H3,6HBASES ,2X,2HDO,F5.1,1X,4HMG/L,F7.2,1X,7HPCT SAT,6X,
   18HNH3  CO2,2X,12HMISSING DATA)
    GO TO 503
498 WRITE(6,478)NH3
478 FORMAT(1H3,6HBASES ,2X,2HDO,2X,12HMISSING DATA,2X,3HNH3,F5.1,1X,
   14HMG/L,2X,3HCO2,2X,12HMISSING DATA)
    GO TO 503
497 WRITE(6,477)DO,DO1,CO2
477 FORMAT(1H3,6HBASES ,2X,2HDO,F5.1,1X,4HMG/L,F7.2,1X,7HPCT SAT,2X,
   13HNH3,1X,12HMISSING DATA,2X,3HCO2,F5.1,1X,4HMG/L)
503 WRITE(6,261)
261 FORMAT(1H3,14HORGANIC MATTER,19X,9HORGANISMS)
    Z1=SIGN(Z1,BOD)
    Z2=SIGN(Z2,TOTCNT)
    KLK=Z1+.5*Z2+2.55
    GO TO(504,505,506,507),KLK
504 WRITE(6,600)
600 FORMAT(1H0,5X,3HBOD,6X,12HMISSING DATA,11X,11HTOTAL COUNT,6X,
   112HMISSING DATA)
    GO TO 510
505 WRITE(6,601)TOTCNT
601 FORMAT(1H0,5X,3HBOD,6X,12HMISSING DATA,11X,11HTOTAL COUNT,F17.0,
   16H/100ML)
    GO TO 510
506 WRITE(6,602)BOD
602 FORMAT(1H0,5X,3HBOD,F8.2,1X,4HMG/L,16X,11HTOTAL COUNT,6X,
   112HMISSING DATA)
    GO TO 510
507 WRITE(6,603)BOD,TOTCNT
603 FORMAT(1H0,5X,3HBOD,F8.2,1X,4HMG/L,16X,11HTOTAL COUNT,F17.0,
   16H/100ML)
510 Z1=SIGN(Z1,COLOR)
    Z2=SIGN(Z2,COLIFM)
    KLK=Z1+.5*Z2+2.55
    GO TO(514,515,516,517),KLK
514 WRITE(6,604)
604 FORMAT(1H0,5X,5HCOLOR,4X,12HMISSING DATA,11X,9HCOLIFORMS,8X,
   112HMISSING DATA)
    GO TO 520
515 WRITE(6,605)COLIFM
605 FORMAT(1H0,5X,5HCOLOR,4X,12HMISSING DATA,11X,9HCOLIFORMS,F19.0,
   16H/100ML)
    GO TO 520
516 WRITE(6,606)COLONL,COLOR
606 FORMAT(1H0,5X,5HCOLOR,1X,A1,F4.0,1X,12HCOBALT UNITS,8X,
   19HCOLIFORMS,8X,12HMISSING DATA)
    GO TO 520
517 WRITE(6,607)COLONL,COLOR,COLIFM
607 FORMAT(1H0,5X,5HCOLOR,1X,A1,F4.0,1X,12HCOBALT UNITS,8X,
   19HCOLIFORMS,F19.0,6H/100ML)
520 Z1=SIGN(Z1,Q)
    Z2=SIGN(Z2,PLANKT)
    KLK=Z1+.5*Z2+2.55
    GO TO(524,525,526,527),KLK
524 WRITE(6,608)
608 FORMAT(1H0,5X,3H Q ,6X,12HMISSING DATA,11X,9HPLANKTERS,8X,
   112HMISSING DATA)
    GO TO 530
525 WRITE(6,609)PLANKT
609 FORMAT(1H0,5X,3H Q ,6X,12HMISSING DATA,11X,9HPLANKTERS,F19.0,
   13H/ML)
    GO TO 530
526 WRITE(6,610)Q
610 FORMAT(1H0,5X,3H Q ,F8.1,2X,3HCFS,16X,9HPLANKTERS,8X,
   112HMISSING DATA)
    GO TO 530
527 WRITE(6,611)Q,PLANKT
611 FORMAT(1H0,5X,3H Q ,F8.1,2X,3HCFS,16X,9HPLANKTERS,F19.0,3H/ML)
530 Z=SIGN(Z,PHB)
    IF(Z.LT.0.)GO TO 531
    WRITE(6,612)PHB
612 FORMAT(1H0,5X,13HPH DET IN LAB,F8.2)
    GO TO 501
531 WRITE(6,613)
613 FORMAT(1H0,5X,24HPH NOT DETERMINED IN LAB)
501 WRITE(6,265)
265 FORMAT(1H3,16HOTHER PARAMETERS)
    Z1=SIGN(Z1,PHF)
    Z2=SIGN(Z2,T)
    KLK=Z1+.5*Z2+2.55
    GO TO(534,535,536,537),KLK
534 WRITE(6,614)
614 FORMAT(1H0,5X,5HPH(F),6X,12HMISSING DATA,6X,14HTEMPERATURE (F),6X,
   112HMISSING DATA)
    GO TO 540
535 WRITE(6,615)T
615 FORMAT(1H0,5X,5HPH(F),6X,12HMISSING DATA,6X,14HTEMPERATURE (F),
   1F7.1,1X,15HDEG. CENTIGRADE)
    GO TO 540
536 WRITE(6,616)PHF
616 FORMAT(1H0,5X,5HPH(F),F16.1,8X,14HTEMPERATURE (F),6X,
   112HMISSING DATA)
    GO TO 540
537 WRITE(6,617)PHF,T
617 FORMAT(1H0, 5X,5HPH(F),F16.1,8X,14HTEMPERATURE (F),F7.1,1X,
   115HDEG. CENTIGRADE)
540 Z1=SIGN(Z1,TURB)
    Z2=SIGN(Z2,TDS)
    KLK=Z1+.5*Z2+2.55
    GO TO(544,545,546,547),KLK
544 WRITE(6,618)
618 FORMAT(1H0,5X,9HTURBIDITY,6X,12HMISSING DATA,2X,3HTDS,6X,
   112HMISSING DATA)
    GO TO 550
545 WRITE(6,619)TDS
619 FORMAT(1H0,5X,9HTURBIDITY,6X,12HMISSING DATA,2X,3HTDS,F18.1,1X,
   14HMG/L)
    GO TO 550
546 WRITE(6,620)TURBL,TURB
620 FORMAT(1H0,5X,9HTURBIDITY,6X,A1,F4.0,9X,3HTDS,6X,12HMISSING DATA)
    GO TO 550
547 WRITE(6,621)TURBL,TURB,TDS
621 FORMAT(1H0,5X,9HTURBIDITY,6X,A1,F4.0,9X,3HTDS,F18.1,1X,4HMG/L)
550 Z1=SIGN(Z1,COND)
    Z2=SIGN(Z2,SIO2)
    KLK=Z1+.5*Z2+2.55
    GO TO(554,555,556,557),KLK
554 WRITE(6,622)
622 FORMAT(1H0,5X,12HCONDUCTIVITY,3X,12HMISSING DATA,2X,4HSIO2,6X,
   112HMISSING DATA)
    GO TO 560
555 WRITE(6,623)SIO2
623 FORMAT(1H0,5X,12HCONDUCTIVITY,3X,12HMISSING DATA,2X,4HSIO2,F17.1,
   11X,4HMG/L)
    GO TO 560
556 WRITE(6,624)COND
624 FORMAT(1H0,5X,12HCONDUCTIVITY,F8.0,1X,5HUMHOS,3X,4HSIO2,6X,
   112HMISSING DATA)
    GO TO 560
557 WRITE(6,625)COND,SIO2
625 FORMAT(1H0,5X,12HCONDUCTIVITY,F8.0,1X,5HUMHOS,3X,4HSIO2,F17.1,1X,
   14HMG/L)
560 Z=SIGN(Z,HARD)
    IF(Z.LT.0.)GO TO 565
    WRITE(6,626)HARD
626 FORMAT(1H0,5X,23HTOTAL HARDNESS AS CACO3,F7.2,1X,4HMG/L)
    GO TO 570
565 WRITE(6,627)
627 FORMAT(1H0,5X,23HTOTAL HARDNESS AS CACO3,6X,12HMISSING DATA)
570 GO TO 1
 80 WRITE(6,400) L
400 FORMAT(14H1DATA CARD NO., I3, 16H IS OUT OF ORDER)
    GO TO 90
 90 STOP
    END
```


Group I - Control Card
Group II - Name Cards
Data for Station 1
Data for Station 2
Group III - Data Cards in lots of 6
1
2
3
4
5
6
1
2
3
4
5
6

```
   [illegible]
     [illegible]
   5125  270112 LITTLE BEAR RIVER AT WELLSVILLE TELEMETRY SITE
   5127  271119 LITTLE BEAR RIVER BELOW WELLSVILLE
   5128  272137 LITTLE BEAR RIVER AT WELLSVILLE LOWER BRIDGE
   5152  254393 LITTLE BEAR RIVER AT SALT LAKE MERIDIAN
   5164  279086 HYRUM RESERVOIR AT STATE PARK BOAT RAMP
   5205  287701 LITTLE BEAR RIVER AT PARADISE TELEMETRY SITE
   5213  287028 LITTLE BEAR RIVER AT PARADISE LOWER BRIDGE
   5224  295012 LITTLE BEAR RIVER AT WHITES TROUT FARM DIVERSION
   5246  309488 LITTLE BEAR RIVER AT WEST CANYON BELOW AVON
   5273  326457 LITTLE BEAR RIVER BELOW DAVENPORT CREEK NEAR AVON
   5274  322950 SOUTH FORK LITTLE BEAR RIVER BELOW DAVENPORT CREEK
   5275  320948 SOUTH FORK LITTLE BEAR RIVER ABOVE DAVENPORT CREEK
  SECO4  321977 EAST FORK LITTLE BEAR RIVER AT AVON
  SECN3  376965 EAST FORK LITTLE BEAR RIVER BELOW PORCUPINE DAM
  SECN7  405961 EAST FORK LITTLE BEAR RIVER ABOVE PORCUPINE RESERVOIR
   5303  321465 DAVENPORT CREEK AT SOUTH FORK LITTLE BEAR RIVER
   SW01  279106 WELLSVILLE STREAM AT LOWER WELLSVILLE ROAD
  SIFDU  288028 WHITES TROUT FARM AT PARADISE LOWER BRIDGE
  SLP07  346313 LOGAN RIVER AT HIGHWAY BRIDGE ABOVE STATE DAM
  U2211  235110 ARTESIAN WELL EAST OF ARCHIBALD ROAD
  U2611  258178 FIELD DRAIN 1 MILE EAST OF GREENS CORNER
  U2407  298068 SPRING AT E N ISRAELSEN FARM
  U3193  312985 SPRING AT FORSBERG ROAD
  U2510  258107 LADELL ANDERSON FIELD DRAIN
   5125  070168  0940 SLIGHTLY TURBID
   5125  070168  0940 TELEMETRY SITE
   5125  070168  0940 CLEAR
   5125  070168  0940
   5125 070168180940 217          330  63 186  95 207  00  76  06 131  78
   5125 070168183  86  01      84- 25 5303950 130 190 114  11-  5176E432012
   5128  070168  0955 CLEAR
   5128  070168  0955 ADJACENT TO BRIDGE
   5128  070168  0955 SUNNY
   5128  070168  0955
   5128 070168182 0955 262        352  60 164  90 225  00  22  01 128  77
   5128 070168183  89  03      83- 25 5603810 140 225 107  02-  5140E3300E1
 ## REMOTE STOP
```

Figure C-7. Continued.

Table C-1. Input data cards for Program QULPRT.

Group	Card	Column	Name	Format	Description
I	1		NSTATS	I5	Number of stations for which sample data are punched
II	2 to 2_{NSTATS}	1-6	Name_1	A6	Mnemonic station designation
		7-8	blank	2X	blank
		8-13	Name_2	A6	UMT grid coordinates of station
		14-78	Name_3-Name_{18}	16A4	Station name and description
III	1	1-6	STI	A6	Six character station mnemonic
		9-14	DATE	A6	Date of sample collection as MO/DA/YR
		17-20	TIME	A4	Time sample was taken in military time
		21-79	APPEAR	14A4,A3	Appearance of the sampled water
		80	L	I1	1, signifying card one of data group III
	2	1-20	Same as on Card 1 above		
		21-79	COLL	14A4,A3	Detailed description of the point of collection of the sample
		80	L	I1	2, signifying card two of data group III
	3	1-20	Same as on Card 1 above		
		21-79	WCOND	14A4,A3	Weather condition at time sample taken
		80	L	I1	3, signifying card three of data group III
	4	1-20	Same as on Card 1 above		
		21-79	CMNTS	14A4,A3	Comments describing any unusual circumstances concerning the sample
	5	1-6	ST1	A6	Six character station mnemonic
		8-13	DATE	A6	Date of sample in MO/DA/YR
		14-16	JULDAY	A3	Consecutive day of year
		17-20	TIME	A4	Time of day of sample in military time
		21-24	CA	F4.1	Calicium in milligrams per liter (mg/l)
		25-28	CU	F4.1	Copper in mg/l
		29-32	FE	F4.1	Iron in mg/l
		33-36	MG	F4.1	Magnesium in mg/l
		37-40	K	F4.1	Potassium in mg/l
		41-44	NA	F4.1	Sodium in mg/l
		45-48	CL	F4.1	Chloride in mg/l
		49-52	B	F4.1	Total ml .02N acid titration to reach methyl range end point
		53-56	A	F4.1	ml .02N acid titrant to reach phenolphthalein end point
		57-60	NO3	F4.1	nitrate in mg/l
		61-64	PO4	F4.1	phosphate in mg/l
		65-68	SO4	F4.1	sulfate in mg/l
		69-72	PHF	F4.1	field pH

Table C-1. Continued.

Group	Card	Column	Name	Format	Description
	6	1-16	Same as card 5 above		
		17-20	DO	F4.1	Dissolved oxygen in mg/l
		21-24	NH3	F4.1	Ammonia in mg/l
		25-28	CO2	F4.1	Carbon dioxide in mg/l
		29-32	Ph	F4.1	pH in the laboratory sample
		33	TURBL	A1	inequality condition for turbidity measurement + for > and - for <
		34-36	TURB	F3.0	Turbidity
		37-40	COND	F4.0	Electrical conductivity in μmhos/cm
		41-44	TDS	F4.1	Total dissolved solids in mg/l
		45-48	T	F4.1	Field temperature in °C.
		49-52	HARD	F4.0	Total hardness as $CaCO_3$ in mg/l
		53-56	SIO2	F4.1	silicon dioxide in mg/l
		57-60	BOD	F4.1	Biological oxygen demand in mg/l
		61	COLORL	A1	inequality condition for color measurement + for >, - for <
		62-64	COLOR	F3.0	Color in cobalt units
		65-69	TOTCNT	E5.0*	Total organism count per 100 ml
		70-74	COLIFM	E5.0	Coliform count per 100 ml
		75-79	FECOL	E5.0	Fecal coliform count per 100 ml
		80	LL	I1	6, signifying card 6 of data group III

*Example: if total count is measured as 5,800,000 per 100 ml, the card would be punched: 580 + 4, with the 5 in column 65.

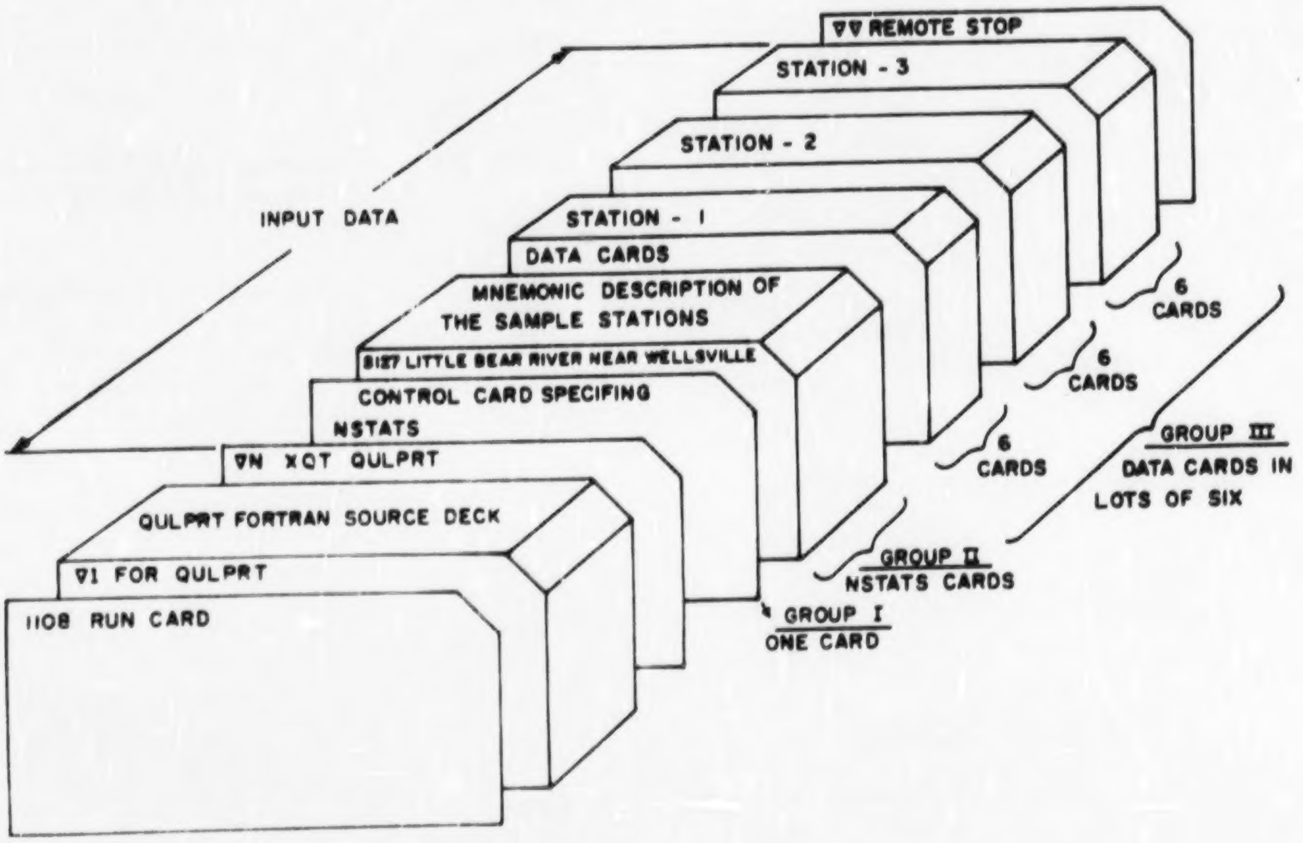
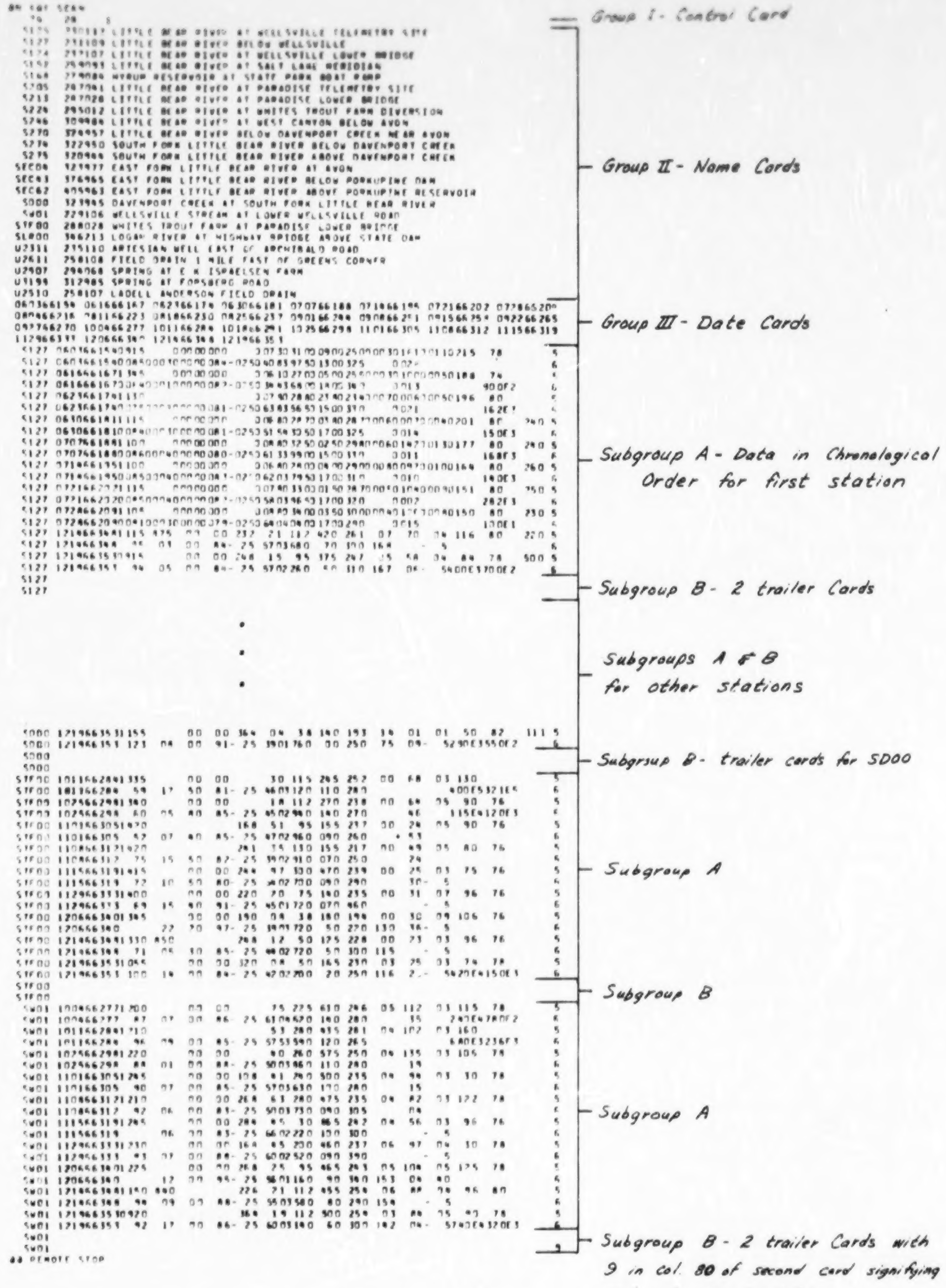

▽▽ REMOTE STOP
STATION - 3
STATION - 2
INPUT DATA
STATION - 1
DATA CARDS
MNEMONIC DESCRIPTION OF THE SAMPLE STATIONS
8127 LITTLE BEAR RIVER NEAR WELLSVILLE
CONTROL CARD SPECIFING NSTATS
▽N XQT QULPRT
QULPRT FORTRAN SOURCE DECK
▽1 FOR QULPRT
1108 RUN CARD
6 CARDS
6 CARDS
6 CARDS
GROUP III DATA CARDS IN LOTS OF SIX
GROUP II NSTATS CARDS
GROUP I ONE CARD

Figure C-8. Deck set-up for QULPRT data input.

```
•1 FOR SCAN,SCAN
C  C  SCAN OF QUALITY DATA BY DATE AND STATION
C     READ STATION NAME CARDS FOR AT LEAST ALL STATIONS SCANNED
C     READ DATE CARDS FOR ALL WEEKS DESIRED SCANNED
C     DATA INPUT SORTED ACCORDING TO STATION WITH DATES CHRONOLOGICAL
C     DATA FOR STATIONS SEPARATED BY 2 CARDS WITH 0'S IN COL 80
C     LAST 2 CARDS SHOULD HAVE 0 IN COL 80 AND 9 IN COL 80 RESPECTIVELY
C     DATA OUTPUT IS IN SAME SEQUENCE AS READ IN INPUT
      REAL MG(25,53),K(25,53),NA(25,53),NO3(25,53),NH3(25,53),Q(25,53),
     1CA(25,53),CU(25,53),FE(25,53),CL(25,53),B(25,53),A(25,53),
     2PO4(25,53),PHF(25,53),HARD(25,53),DO(25,53),DO1(25,53),CO2(25,53),
     3PH(25,53),TURBL(25,53),TURB(25,53),COND(25,53),TDS(25,53),T(25,53)
     4,SIO2(25,53),BOD(25,53),COLORL(25,53),COLOR(25,53),TOTCNT(25,53),
     5COLIFM(25,53),SO4(25,53),HCO3(25,53),CO3(25,53)
      INTEGER ST1(25),NAME(25,18),N(25),JULDAY(25,53),IJUL(53),
     1IDATE(53),DATE(25,53),TIME(25,53)
      DATA BLANK/5H     /
    1 READ(5,201) NSTATS,NWEEKS,IOUT
  201 FORMAT(3I5)
      DO 51 I=1,NSTATS
   51 READ(5,202)(NAME(I,J),J=1,18)
  202 FORMAT(A6,2X,A6,16A4)
      READ(5,205)(IDATE(J),IJUL(J),J=1,NWEEKS)
  205 FORMAT(8(1XA6,A3))
      NIMAX=0
      NS=0
      Z=1.
      DO 10 I=1,25
      DO 11 J=1,53
      READ(5,100)ST1(I),DATE(I,J),JULDAY(I,J),TIME(I,J),CA(I,J),CU(I,J),
     1FE(I,J),MG(I,J),K(I,J),NA(I,J),CL(I,J),B(I,J),A(I,J),NO3(I,J),PO4(
     2I,J),SO4(I,J),PHF(I,J),Q(I,J),L,DO(I,J),NH3(I,J),CO2(I,J),
     3PH(I,J),TURBL(I,J),TURB(I,J),COND(I,J),TDS(I,J),T(I,J),
     4HARD(I,J),SIO2(I,J),BOD(I,J),COLORL(I,J),COLOR(I,J),TOTCNT(I,J),
     5COLIFM(I,J),LL
  100 FORMAT(A6,1X,A6,A3,A4,13F4.1,F6.1,1X,I1/16X,4F4.1,A1,F3.0,F4.0,
     12F4.1,F4.0,2F4.1,A1,F3.0,2E5.0,5X,I1)
      IF(L.NE.0) GO TO 40
      N(I)=J-1
      IF(N(I).LT.NIMAX)GO TO 12
      NIMAX=N(I)
      MAXS=I
      GO TO 12
   40 IF(L.NE.5)GO TO 1000
      IF(LL.NE.6)GO TO 1000
   11 CONTINUE
   12 NS=NS+1
      IF(LL.EQ.9)GO TO 61
   10 CONTINUE
   61 DO 20 I=1,NS
      M=N(I)
      DO 20 J=1,M
      Z=SIGN(Z,CA(I,J))
      IF(Z.LT.0.)CA(I,J)=100000000.
      Z=SIGN(Z,CU(I,J))
      IF(Z.LT.0.)CU(I,J)=100000000.
      Z=SIGN(Z,FE(I,J))
      IF(Z.LT.0.)FE(I,J)=100000000.
      Z=SIGN(Z,MG(I,J))
      IF(Z.LT.0.)MG(I,J)=100000000.
      Z=SIGN(Z,K(I,J))
      IF(Z.LT.0.)K(I,J)=100000000.
      Z=SIGN(Z,NA(I,J))
      IF(Z.LT.0.)NA(I,J)=100000000.
      Z=SIGN(Z,CL(I,J))
      IF(Z.LT.0.)CL(I,J)=100000000.
      HCO3(I,J)=12.2*(B(I,J)-2.0*A(I,J))
      Z=SIGN(Z,B(I,J))
      IF(Z.LT.0.)HCO3(I,J)=100000000.
      CO3(I,J)=12.*A(I,J)
      Z=SIGN(Z,A(I,J))
      IF(Z.LT.0.)CO3(I,J)=100000000.
      Z=SIGN(Z,NO3(I,J))
      IF(Z.LT.0.)NO3(I,J)=100000000.
      Z=SIGN(Z,PO4(I,J))
      IF(Z.LT.0.)PO4(I,J)=100000000.
      Z=SIGN(Z,SO4(I,J))
      IF(Z.LT.0.)SO4(I,J)=100000000.
      Z=SIGN(Z,PHF(I,J))
      IF(Z.LT.0.)PHF(I,J)=100000000.
      Z=SIGN(Z,Q(I,J))
      IF(Z.LT.0.)Q(I,J)=100000000.
      Z=SIGN(Z,HARD(I,J))
      IF(Z.LT.0.)HARD(I,J)=100000000.
      DO1(I,J)=1000./(81.3+(2.462*T(I,J)))
      DO1(I,J)=(DO(I,J)/DO1(I,J))*100.
      Z=SIGN(Z,DO(I,J))
      IF(Z.LT.0.)DO(I,J)=100000001.
      Z=SIGN(Z,T(I,J))
      IF(Z.LT.0.)T(I,J)=100000000.
      IF(Z.LT.0..OR.DC(I,J).GT.100000000.)DC1(I,J)=DO(I,J)
      Z=SIGN(Z,NH3(I,J))
      IF(Z.LT.0.)NH3(I,J)=100000000.
      Z=SIGN(Z,CO2(I,J))
      IF(Z.LT.0.)CO2(I,J)=100000000.
      Z=SIGN(Z,PH(I,J))
      IF(Z.LT.0.)PH(I,J)=100000000.
      Z=SIGN(Z,TURB(I,J))
      IF(Z.LT.0.)TURB(I,J)=100000000.
      Z=SIGN(Z,COND(I,J))
      IF(Z.LT.0.)COND(I,J)=100000000.
      Z=SIGN(Z,TDS(I,J))
      IF(Z.LT.0.)TDS(I,J)=100000000.
      Z=SIGN(Z,SIO2(I,J))
      IF(Z.LT.0.)SIO2(I,J)=100000000.
      Z=SIGN(Z,BOD(I,J))
      IF(Z.LT.0.)BOD(I,J)=10000000000.
      Z=SIGN(Z,COLOR(I,J))
      IF(Z.LT.0.)COLOR(I,J)=10000000000.
      Z=SIGN(Z,TOTCNT(I,J))
      IF(Z.LT.0.)TOTCNT(I,J)=1000000000000.
      Z=SIGN(Z,COLIFM(I,J))
      IF(Z.LT.0.)COLIFM(I,J)=100000000000.
   20 CONTINUE
      WRITE(6,401)MAXS,NS,(N(I),I=1,NS)
  401 FORMAT(1H1,7H MAXS =,I4,5H NS =,I4,7H N(I) =,30I4)
      GO TO(130,130,150),IOUT
  130 DO 22 I=1,NS
      KK=0
      DO 135 K1=1,NSTATS
      IF(ST1(I).EQ.NAME(K1,1)) GO TO 131
  135 CONTINUE
      WRITE(6,1002)ST1(I)
 1002 FORMAT(1H1,8HSTATION ,A6,15H NAME NOT FOUND)
      KK=1
      GO TO 136
  131 WRITE(6,104)(NAME(K1,J),J=1,18)
  104 FORMAT(1H1,8HSTATION ,A6,2X,A6,1X,16A4)
  136 WRITE(6,101)
  101 FORMAT(1H0,30X,12HGASES (MG/L),19X,16HOTHER PARAMETERS,
     17H (MG/L),9X,21HORGANIC MATTER (MG/L),4X,9HORGANISMS)
      WRITE(6,110)
      WRITE(6,111)
      M=N(I)
      DO 23 J=1,M
   23 WRITE(6,112)ST1(I),DATE(I,J),TIME(I,J),DO(I,J),DO1(I,J),NH3(I,J),
     1CO2(I,J),TURBL(I,J),TURB(I,J),COND(I,J),TDS(I,J),T(I,J),SIO2(I,J),
     3BOD(I,J),COLORL(I,J),COLOR(I,J),TOTCNT(I,J),COLIFM(I,J)
      IF(KK)137,138,137
  137 WRITE(6,1002)ST1(I)
  138 IF(KK.EQ.0)WRITE(6,104)(NAME(K1,J),J=1,18)
      WRITE(6,301)
  301 FORMAT(1H0,34X,14HCATIONS (MG/L),28X,13HANIONS (MG/L),21X,
     116HOTHER PARAMETERS)
      WRITE(6,106)
      DO 22 J=1,M
      WRITE(6,303)ST1(I),DATE(I,J),TIME(I,J),CA(I,J),CU(I,J),FE(I,J),
     1MG(I,J),K(I,J),NA(I,J),CL(I,J),HCO3(I,J),CO3(I,J),NO3(I,J),
     2PO4(I,J),SO4(I,J),PHF(I,J),PH(I,J),HARD(I,J),Q(I,J)
  303 FORMAT(2XA6,1XA6,1XA4,1XF5.1,11(2XF5.1),3XF3.1,4XF3.1,3XF5.1,3XF5.
     11)
   22 CONTINUE
      GO TO (150,1,150),IOUT
  150 DO 24 K1=1,NWEEKS
      KK1=1
      DO 25 I=1,NS
      M=N(I)
      DO 125 J=1,M
      IF(ABS(JULDAY(I,J)-IJUL(K1))-2)310,310,125
  125 CONTINUE
      GO TO 25
  310 GO TO (311,312),KK1
  311 KK1=2
      WRITE(6,109)IDATE(K1),IJUL(K1)
  109 FORMAT(1H1,18HDATA FOR THE WEEK ,A6,12H DAY OF YEAR,1XA3)
      WRITE(6,301)
      WRITE(6,106)
  106 FORMAT(8H STATION6H  DATE2X4HTIME3X2HCA5X2HCU5X2HFE5X2HMG6X1HK5X,
     12HNA,5X,2HCL,4X,4HHCO3,4X,3HCO3,4X,3HNO3,4X,3HPO4,4X,3HSO4,3X,
     23HPHF,4X,3HPHL,4X4HHARD,6X1HQ)
  312 WRITE(6,303)ST1(I),DATE(I,J),TIME(I,J),CA(I,J),CU(I,J),FE(I,J),
     1MG(I,J),K(I,J),NA(I,J),CL(I,J),HCO3(I,J),CO3(I,J),NO3(I,J),
     2PO4(I,J),SO4(I,J),PHF(I,J),PH(I,J),HARD(I,J),Q(I,J)
   25 CONTINUE
      KK1=1
  110 FORMAT(8H STATION6H  DATE,2X4HTIME6X2HDO3X7HPCT SAT4X3HNH35X3HCO2,
     14X4HTURB,4X,4HCOND,5X,3HTDS,4X,4HTEMP,4X,4HSIO2,5X,3HBOD,4X,
     15HCOLOR,5X,6HTOTCNT,5X,6HCOLIFM)
  111 FORMAT(1H ,62X,8HUMHOS/CM,9X,6HDEG. C,29X,6H/100ML,5X,6H/100ML)
      DO 26 I=1,NS
      M=N(I)
      DO 126 J=1,M
      IF(ABS(JULDAY(I,J)-IJUL(K1))-2)320,320,126
  126 CONTINUE
      GO TO 26
  320 GO TO (321,322),KK1
  321 KK1=2
      WRITE(6,101)
      WRITE(6,110)
      WRITE(6,111)
  322 WRITE(6,112)ST1(I),DATE(I,J),TIME(I,J),DO(I,J),DO1(I,J),NH3(I,J),
     1CO2(I,J),TURBL(I,J),TURB(I,J),COND(I,J),TDS(I,J),T(I,J),SIO2(I,J),
     3BOD(I,J),COLORL(I,J),COLOR(I,J),TOTCNT(I,J),COLIFM(I,J)
  112 FORMAT(2XA6,1XA6,1XA4,2XF6.1,4XF5.1,3XF5.1,3XF5.1,2XA1,F5.0,2XF6.0
     1,3X,4(F5.1,3X),1XA1,1XF3.0,2(2XF9.0))
   26 CONTINUE
   24 CONTINUE
      GO TO 1
 1000 WRITE(6,113)
  113 FORMAT(1H1,20HCARD IS OUT OF ORDER)
      STOP
      END
```

Figure C-9. Program listing of SCAN and input data set-up for a run.



```
BM SQF SCAN
  70   28      8
  S125  280117 LITTLE BEAR RIVER AT WELLSVILLE TELEMETRY SITE
  S127  231109 LITTLE BEAR RIVER BELOW WELLSVILLE
  S124  237107 LITTLE BEAR RIVER AT WELLSVILLE LOWER BRIDGE
  S152  259093 LITTLE BEAR RIVER AT SALT LAKE MERIDIAN
  S160  279080 HYRUM RESERVOIR AT STATE PARK BOAT RAMP
  S205  287081 LITTLE BEAR RIVER AT PARADISE TELEMETRY SITE
  S213  287028 LITTLE BEAR RIVER AT PARADISE LOWER BRIDGE
  S226  295012 LITTLE BEAR RIVER AT WHITES TROUT FARM DIVERSION
  S246  309984 LITTLE BEAR RIVER AT WEST CANYON BELOW AVON
  S270  379957 LITTLE BEAR RIVER BELOW DAVENPORT CREEK NEAR AVON
  S274  322950 SOUTH FORK LITTLE BEAR RIVER BELOW DAVENPORT CREEK
  S275  320944 SOUTH FORK LITTLE BEAR RIVER ABOVE DAVENPORT CREEK
 SEC04  323977 EAST FORK LITTLE BEAR RIVER AT AVON
 SEC43  376965 EAST FORK LITTLE BEAR RIVER BELOW PORKUPINE DAM
 SEC62  405963 EAST FORK LITTLE BEAR RIVER ABOVE PORKUPINE RESERVOIR
  SD00  323945 DAVENPORT CREEK AT SOUTH FORK LITTLE BEAR RIVER
  SW01  229106 WELLSVILLE STREAM AT LOWER WELLSVILLE ROAD
 STF00  280028 WHITES TROUT FARM AT PARADISE LOWER BRIDGE
 SLR00  366213 LOGAN RIVER AT HIGHWAY BRIDGE ABOVE STATE DAM
 U2311  235110 ARTESIAN WELL EAST OF ARCHIBALD ROAD
 U2611  258108 FIELD DRAIN 1 MILE EAST OF GREENS CORNER
 U2907  294068 SPRING AT E K ISRAELSEN FARM
 U3199  312985 SPRING AT FORSBERG ROAD
 U2510  258107 LADELL ANDERSON FIELD DRAIN
060366154 061666167 062366174 063066181 070766188 071466195 072166202 072866209
080466216 081166223 081866230 082566237 090166244 090866251 091566258 092266265
092766270 100466277 101166284 101866291 102566298 110166305 110866312 111566319
112966333 120666340 121466348 121966353
  S127 0603661540915      00000000      30730310009002500003016130110215  78        5
  S127 0603661540085000100000084-0250408397501300325      0028                     6
  S127 0616661671345      00000000      30610270305002500003010000050188  74        5
  S127 06166616730040001000000082-02503843680014053 67      0013          900E2    6
  S127 0623661741130                    307902800219021400070006300050196  80        5
  S127 06236617400000000000000081-0250638356531500310      0021          162E1    6
  S127 0630661811115      00000000      30680287303802873006000700 60201  80    240 5
  S127 06306618100840001000000081-0253515433501700325      0014          150E3    6
  S127 0707661881100      00000000      30880325002502980006014271030177  80    240 5
  S127 07076618800860004000000080-0253613399001500319      0011          168E3    6
  S127 0714661951100      00000000      30680280308002900008009700100164  80    260 5
  S127 07146619500850004000000083-0250620379501700310      0010          140E3    6
  S127 0721662021115      00000000      30790330301502870008010400090151  80    250 5
  S127 07216620200850004000000082-0250580396531700320      0002          282E3    6
  S127 0728662091105      00000000      30880340003503000004012700080150  80    230 5
  S127 07286620900810003000000079-0250640409031700290      0015          100E1    6
  S127 1214663481115 475   00  00 232  21 112 420 261  07  70  04 116  80    220 5
  S127 121466348   95  03  00  84- 25 5703680  70 390 164    -  5                6
  S127 1219663530915        00  00 248  15  95 375 247  05  58  04  84  78    500 5
  S127 121966353   94  05  00  84- 25 5702260  50 310 167  04-   5400E1700E2     6
  S127
  S127

                        •

                        •

                        •

  SD00 1219663531155       00  00 364  04  38 140 193  14  01  01  50  82    111 5
  SD00 121966353 123   04  00  91- 25 3901760  00 250  75  09-   5290E1550E2     6
  SD00
  SD00
 STF00 1011662841335      00  00      30 115 245 252  00  68  03 130              5
 STF00 101166284   59  17  50  81- 25 4603120 110 280              400E5321E5     6
 STF00 1025662981340      00  00      18 112 270 238  00  64  05  90  76         5
 STF00 102566298   60  05  80  85- 25 4502960 140 270         46    115E4120E3     6
 STF00 1101663051470           168  51  95 155 237  00  24  05  90  76         5
 STF00 110166305   52  07  40  85- 25 4702960 090 260        + 53                 6
 STF00 1108663121420           241  35 130 155 217  00  49  05  80  76         5
 STF00 110866312   75  15  50  82- 25 3902910 070 250         24                  6
 STF00 1115663191415      00  00 244  97 300 470 239  00  25  03  75  76         5
 STF00 111566319   72  10  50  80- 25 4402700 090 290         30-  5              6
 STF00 1129663331400      00  00 220  70  75 140 235  00  31  07  96  76         5
 STF00 112966333   69  15  40  91- 25 4501720 070 460           -  5              6
 STF00 1206663401345      00  00 190  04  38 180 194  00  30  09 106  76         5
 STF00 120666340      22  70  97- 25 3901720  50 270 130  36-  5              6
 STF00 1214663481330 450          248  12  50 175 228  00  23  03  96  76         5
 STF00 121466348   71  05  30  85- 25 4402720  50 300 115     -  5              6
 STF00 1219663531055      00  00 320  08  50 165 230  03  25  03  74  78         5
 STF00 121966353 100   14  00  84- 25 4202200  20 250 116  2.-   5420E4150E3     6
 STF00
 STF00
  SW01 1004662771200      00  00      75 225 610 246  05 112  03 115  78         5
  SW01 100466277   87  07  00  86- 25 6104620 140 280         35    240E4780E2     6
  SW01 1011662841210                  53 280 435 281  04 102  03 160             5
  SW01 101166284   96  09  00  85- 25 5753590 120 265                680E3236E3     6
  SW01 1025662981220      00  00      40 260 575 250  04 135  03 105  78         5
  SW01 102566298   88  01  00  88- 25 5003960 110 280         19                  6
  SW01 1101663051245      00  00 108  41 280 500 235  04  94  03  30  78         5
  SW01 110166305   90  07  00  85- 25 5703630 170 280         15                  6
  SW01 1108663121210      00  00 268  63 280 475 235  04  82  03 122  78         5
  SW01 110866312   92  06  00  83- 25 5003730 090 305         04                  6
  SW01 1115663191245      00  00 284  45  30 865 242  04  56  03  96  76         5
  SW01 111566319       06  00  83- 25 6602220 100 300            -  5              6
  SW01 1129663331230      00  00 164  45 230 460 237  06  97  04  30  78         5
  SW01 112966333   93  07  00  88- 25 6002520 090 390            -  5              6
  SW01 1206663401225      00  00 268  25  95 465 243  05 104  05 125  78         5
  SW01 120666340      12  00  95- 25 5601160  90 340 153  04  40                 6
  SW01 1214663481150 440          226  21 112 455 254  06  88  04  96  80         5
  SW01 121466348   98  09  00  88- 25 5503580  80 290 154     -  5              6
  SW01 1219663530920                364  19 112 500 254  03  88  05  93  78         5
  SW01 121966353   92  17  00  86- 25 6003140  60 300 182  04-   5740E4320E3     6
  SW01
  SW01                                                                           9
@@ REMOTE STOP
```

Group I - Control Card

Group II - Name Cards

Group III - Date Cards

Subgroup A - Data in Chronological Order for first station

Subgroup B - 2 trailer Cards

Subgroups A & B for other stations

Subgroup B - trailer cards for SD00

Subgroup A

Subgroup B

Subgroup A

Subgroup B - 2 trailer Cards with 9 in col. 80 of second card signifying end of input data

Figure C-9. Continued.

Table C-2. Input data cards for program SCAN.

Group	Card	Column	Name	Format	Description
I	1	1-5	NSTATS	I5	Number of stations for which data is being appended ($1 \leq NSTATS \leq 25$)
		6-10	NWEEKS	I5	Number of weeks for which scan by date is desired ($1 \leq NWEEKS \leq 53$)
		11-15	IOUT	I5	Output option: If 1, scan by station and scan by date. If 2, scan by station only. If 3, scan by date only.
II[1]	2, to	1-6	$Name_1$	A6	Mnemonic station designation
	2_{NSTATS}	7-8	blank	2X	blank
		8-13	$Name_2$	A6	UMT grid coordinates of station
		14-78	$Name_3$-$Name_{18}$	16A4	Station name and description
III	3, to $3_{\frac{NWEEKS}{8}}$	1-80	IDATE,IJUL	(8(1X, A6,A3))	Date (mo/day/year) and day of year for which scan output is to include,[2] punched consecutively 8 per card
IV	$[(4_1$	1-80	quality data		same as card III-5, Table C-1
	$-4_2)$	1-80	quality data		same as card III-6, Table C-1
	5	1-5	$Name_1$	A5	Station designation
		80			0(zero)
	$6]_{NSTATS}$	1-5	$Name_1$	A5	Station designation
		80			0(zero); except 9 if last trailer card

---

[1] Same as Group II cards for QULPRT (see Table C-1).

[2] If sample was obtained on a date different than specified by IDATE, IJUL, and output is desired for this sample, two days latitude is allowed; for example if 1/25/69 25 is specified the sample could be obtained 1/23/69 or 1/27/69 and still be included in the output.

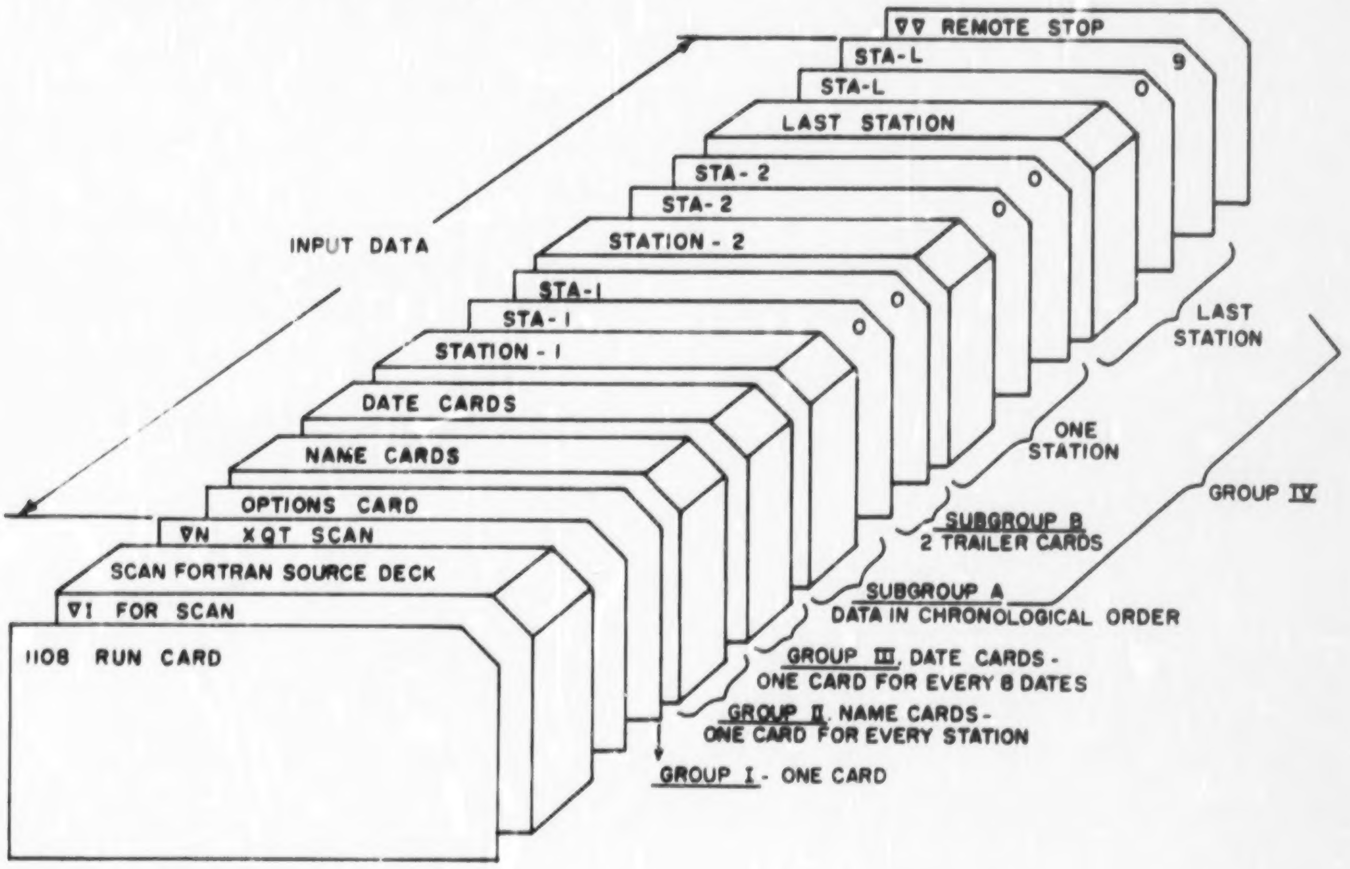

∇∇ REMOTE STOP
STA-L
9
STA-L
0
LAST STATION
STA-2
0
STA-2
0
INPUT DATA
STATION - 2
STA-1
0
STA-1
0
STATION - 1
LAST STATION
DATE CARDS
NAME CARDS
ONE STATION
GROUP IV
OPTIONS CARD
∇N XQT SCAN
SUBGROUP B
2 TRAILER CARDS
SCAN FORTRAN SOURCE DECK
∇I FOR SCAN
SUBGROUP A
DATA IN CHRONOLOGICAL ORDER
1108 RUN CARD
GROUP III, DATE CARDS -
ONE CARD FOR EVERY 8 DATES
GROUP II, NAME CARDS -
ONE CARD FOR EVERY STATION
GROUP I - ONE CARD

Figure C-10. Deck set-up for SCAN data input.

```
@N FOR PRTPLT
C  C   PRINTER PLOT
      DIMENSION NX(300),Y(300,10),A(125,60),AO(300,10),FIN(13),ND(12),
     1B(60),IIX(300),IIY(300,10),ITEST(10),VAR(10),PT(10),YMIN(10),
     2NMIS(10),NYL(10),IS(10),DATE(300),FMT(14)
      DATA BLANK,ZERO,DASH,TICK,ORIG/1H ,1H0,1H-,1HI,6HORIGIN/
      Z=1.
      LL=9
      DO 5 I=1,121
      DO 5 J=1, 60
      B(J)=BLANK
    5 A(I,J)=BLANK
      DO 35 J=1,55
   35 A(2,J)=TICK
      DO 65 J=1,55,6
   65 A(1,J)=DASH
      DO 31 I=3,121
      A(I,1)=DASH
   31 A(I,55)=DASH
      DO 52 I=2,121,10
   52 A(I,56)=TICK
    1 READ(5,201)STA,YEAR,NMP,LP,SCLX,NMIN
  201 FORMAT(A6,A4,2I5,F10.0,I10)
      IF(LL.NE.9)GO TO 71
      READ(5,109)NY,FIN
      READ(5,113)FMT
  113 FORMAT(13A6,A2)
  109 FORMAT(I2,13A6)
      READ(5,110)(VAR(I),PT(I),ITEST(I),I=1,NY)
  110 FORMAT(10(A6,A1,I1))
      READ(5,111)(YMIN(J),J=1,NY)
      READ(5,112)(NYL(J),J=1,NY)
  111 FORMAT(10F8.0)
  112 FORMAT(10I5)
   71 I=0
   30 I=I+1
      READ(5,FIN)DATE(I),NX(I),(Y(I,J),J=1,NY),LL
      IF(LL.EQ.0.OR.LL.EQ.9) GO TO 32
      GO TO 30
   32 N=I-1
      IF (N.LE.0) GO TO 1
      SCXX=10./SCLX
      DO 22 I=1,N
      IIX(I)=SCLX*(NX(I)-NMIN)+2.5
      IF(IIX(I).GT.121)IIX(I)=121
      IF(IIX(I).LT.1)IIX(I)=1
   22 CONTINUE
      DO 4 J=1,NY
    4 NMIS(J)=0.
      ND(1)=NMIN
      DO 41 I=2,12
   41 ND(I)=ND(I-1)+SCXX+.5
      DO 70 J=1,NY
      IF(ITEST(J).EQ.0)GO TO 78
      DO 77 I=1,N
      IF(Y(I,J).LE.0.)GO TO 77
      Y(I,J)=ALOG10(Y(I,J))
   77 CONTINUE
   78 YMAX=Y(1,J)
      DO 10 I=2,N
      IF(Y(I,J).GT.YMAX)YMAX=Y(I,J)
   10 CONTINUE
      S=(YMAX-YMIN(J))/9.
      I=1
      IF( S.LE.1)GO TO 75
      ISI=NYL(J)
      DO 66 I=ISI,10000,ISI
      IF( S.LE.I)GO TO 75
   66 CONTINUE
   75 S=I
      IS(J)=I
      SCLY = 6.0/S
      IF(NMP.NE.0)GO TO 21
      B(1)=YMIN(J)
      DO 20 JI=7,55,6
   20 B(JI)=B(JI-6)+S
   21 DO 15 I=1,N
      IIY(I,J)=SCLY*(Y(I,J)-YMIN(J))+1.5
      IF(IIY(I,J).GT.55)IIY(I,J)=55
      IF(IIY(I,J).LT.1)IIY(I,J)=1
      IX=IIX(I)
      IY=IIY(I,J)
      AO(I,J)=A(IX,IY)
      Z=SIGN(Z,Y(I,J))
      IF(Z)13,14,14
   13 NMIS(J)=NMIS(J)+1
      Y(I,J)=10.E+20
      GO TO 15
   14 A(IX,IY)=PT(J)
   15 CONTINUE
      IF(NMP.NE.0)GO TO 68
      WRITE(6,101) STA,YEAR,VAR(J),IS(J),SCXX,N,NMIS(J)
  101 FORMAT(1H117HDATA FOR STATION ,A6,2H  ,A6,2H  ,A6,2X10HONE INCH =,
     1I4,7H UNITS,16H TIME ONE INCH =,F5.1,5H DAYS,5X6HNOBS =,I5,
     22X6HNMIS =I5)
      DO 85 L=1,55
      IF(B(56-L).EQ.BLANK) GO TO 81
   80 WRITE(6,103)B(56-L),(A(I,56-L),I=1,121)
      GO TO 85
   81 WRITE(6,104)(A(I,56-L),I=1,121)
   85 CONTINUE
  103 FORMAT(1X,F4.0,121(A1))
      WRITE(6,104)(A(I,56),I=1,121)
  104 FORMAT(5X,121A1)
      WRITE(6,108)(ND(I),I=1,12)
  108 FORMAT(1H ,3X,12(I4,6X))
      DO 67 I=1,N
      IX=IIX(I)
      IY=IIY(I,J)
   67 A(IX,IY)=AO(I,J)
      IF(LP.EQ.0)GO TO 70
      IF(J.EQ.NY)GO TO 69
      GO TO 70
   68 IF(J.NE.NY)GO TO 70
   69 WRITE(6,115)STA,YEAR,SCXX,N
  115 FORMAT(32H1MULTIPLE PLOT DATA FOR STATION A6,8H,  YEAR A4,17H, TIM
     1E ONE INCH =,F5.1,6H DAYS,2X6HNOBS =,I5)
      WRITE(6,116)(VAR(K),K=1,NY)
  116 FORMAT(9H0VARIABLE,10(4XA6))
      WRITE(6,117)(PT(K),K=1,NY)
  117 FORMAT(11H PLOT CHAR 5XA1,9(9XA1))
      WRITE(6,FMT)ORIG,NMIN,(YMIN(K),K=1,NY)
      WRITE(6,120)(IS(K),K=1,NY)
  120 FORMAT(11H UNITS/INCHI6,9I10)
      WRITE(6,121)(NMIS(K),K=1,NY)
  121 FORMAT(11H NO MISSING,I6,9I10)
      DO 86 I=1,N
   86 WRITE(6,FMT)DATE(I),NX(I),(Y(I,K),K=1,NY)
      IF(NMP.EQ.0)GO TO 70
      WRITE(6,119)STA,YEAR,(VAR(I),PT(I),I=1,NY)
  119 FORMAT(8H1STATION,A6,A6,10(1XA6,1XA2))
      DO 90 L=55,1,-1
   90 WRITE(6,104)(A(I,L),I=1,121)
      WRITE(6,104)(A(I,56),I=1,121)
      WRITE(6,108)(ND(I),I=1,12)
      DO 91 I=1,N
      DO 91 K=NY,1,-1
      IX=IIX(I)
      IY=IIY(I,K)
   91 A(IX,IY)=AO(I,K)
   70  CONTINUE
      GO TO 1
      END
```

Input Data for Sample Problem

```
@N XQT PRTPLT
 51271966    0    1 .33333333        0
 6(7XA6,I3,4XF5.1,5XF4.0,5XF6.1,F4.1,F6.1,E5.0,19XI1)
(1XA6,I4,F10.2,F10.0,F10.1,F10.0,F10.1,5F10.5)
   DO .0  COND+0  TEMP+0   BOD00  FLOWQ0LG COLC1
      0     100      0       0       0       0
  2    5    2    1    5    1
  5127 0603661540915   85  9630408 0325   1300028                7
  5127 0616661671345   84 10550344 0340   1800013         900E2  7
  5127 0623661741130   75  8870638 0330   1500021         162E3  7
  5127 0630661811115   84 10340515 0325   1 00014      240150E3  7
  5127 0707661881100   86 10170613 0330   1500011      240160E3  7
  5127 0714661951100   85 10470620 0310   1700010      260140E3  7
  5127 0721662021115   85 10470580 0320   1700002      250282E3  7
  5127 0728662091105   81  9980640 0290   1700015      230100E1  7
  5127 0804662161200   81   998 568   330   170   08   260240E2  7
  5127 0811662231100   85 1026 559    320   160   11   220157E3  7
  5127 0818662301145   75   905 275   310   160   23   270780E2  7
  5127 0825662370905   80   906 305   330   130   20   250160E3  7
  5127 0901662440900   67   776 245   300   14    05   270120E3  7
  5127 0908662511015   78   922 310   320   150   08   230980E3  7
  5127 0915662580930   84   910 325   320   110   23   310140E3  7
  5127 09226626599.5   89 1088 618    320   130   32   280460E3  7
  5127 0927662701020   88   975 640   310   120   30   2801 5E4  7
  5127 1004662771155   94 1042 590    300   120   20   290135E3  7
  5127 1011662841205   99 1073 650    285   110        300420E3  7
                                                                 0
  51271966    1    1 .33333333        0
  5127 1025662981215   96 1017 580    280   100   13   220890E2  7
  5127 1101663051230   95 1006 580    320   100   17   200200E2  7
  5127 1108663121220  103 1043 600    300    80   25   240720E2  7
  5127 1115663191230  113 1197 610    310   100   21   200178E3  7
  5127 1129663331220   96   993 610   370    90        200       7
  5127 1206663401220            590   305    80   16   270850E3  7
  5127 1214663481115   95   936 570   300    70        220       7
  5127 1219663530915   94   880 570   310    50   06   500700E2  7
                                                                 9
```

Group I - Control specs for data that follows

Subgroup C - Data for first plot

Subgroup A - Specs for control options - next Batch

Subgroup B - Control specs for data that follows

Subgroup C - Data for next plot

Subgroup A - Same as above

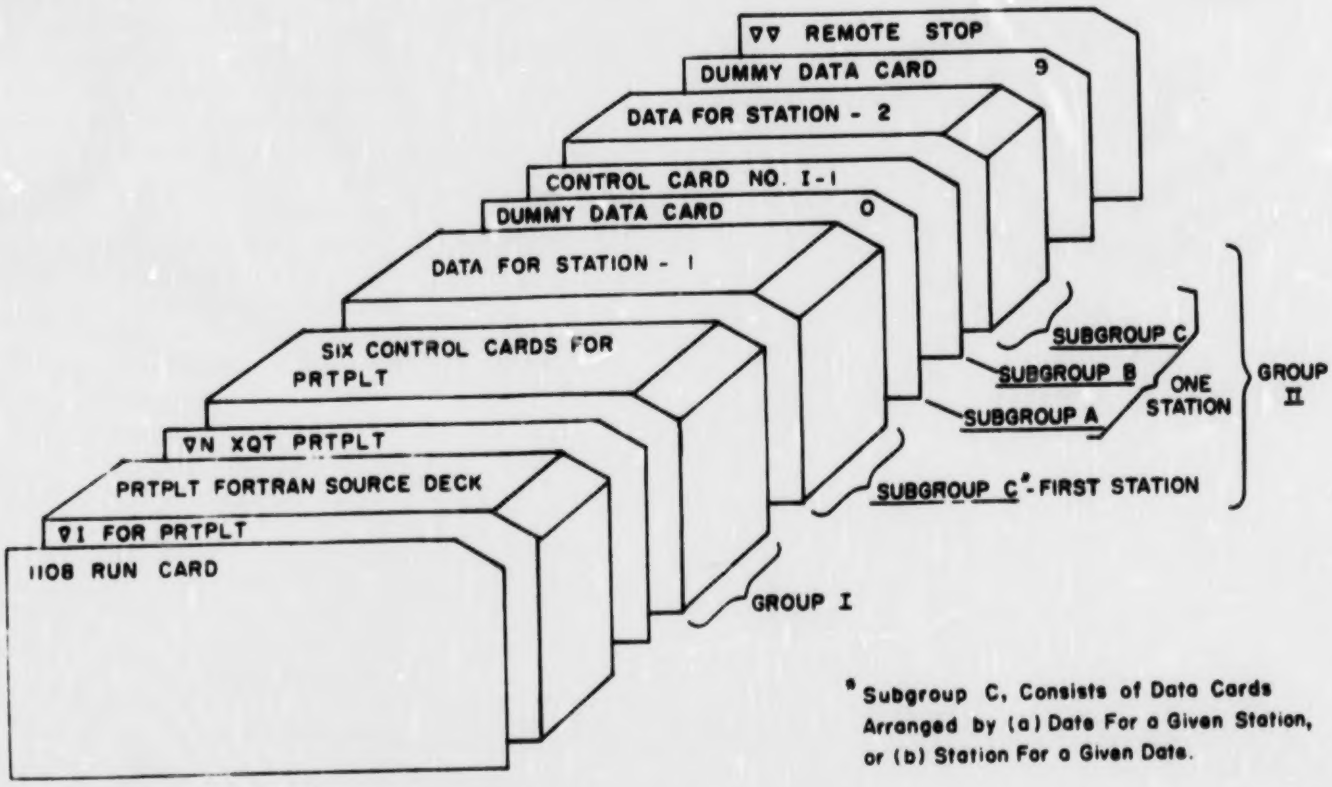
Figure C-11. Program listing of PRTPLT and input data set-up of run.

Table C-3. Input data cards for program PRTPLT.

Group	Card	Column	Name	Format	Description
I	1	1-6	STA	A6	Six character mnemonic symbol identifying the station (i.e. S12.7)
		7-10	YEAR	A4	Four character mnemonic symbol identifying the X axis data (or time period) (a) year data was taken (i.e. 1966), or (b) write DIST here if Fig. C-5 is the desired form of output.
		11-15	NMP	I5	Option specification: If zero plot one Y variable against the X variable If 1 plot all Y variables (the Y array) against the X variable
		16-20	LP	I5	List option when NMP = 0 If zero suppress listing of data If ≠ zero list the input data
		21-30	SCLX	F10.0	Scale factor for the X variable. The X data are plotted in increments of 10/SCLX units per inch.
		31-40	NMIN	I10	Specification of the origin for the X axis.
	2	1-2	NY	I2	Number of separate Y variables to be plotted, 1 ≤ NY ≤ 10.
		3-80	FIN	13A6	Format of the input data which must provide for reading DATE (I), NX(I), (Y(I,J), J=1, NY) and LL in that order. LL is a control variable, read on every data card—where I is the sequence of data to be read in for a given variable, NX is (a) the day of year, or (b) distance, depending upon whether Fig. C-5 or Fig. C-6 type of plot is desired.
	3	1-80	FMT	(13A6,A2)	Format specification for the output list. It must provide for printing DATE(I),NX(I),(Y(I,K), K=1,NY) in that order.
	4	1-6	VAR(1)	A6	Label for the first Y variable
		7	PT(1)	A1	Plotting character for VAR(1)
		8	ITEST(1)	I1	Log_{10} transformation option for the first Y variable. If zero, no transformation is made. If 1, a $\log_{10}$ transformation is made.
		9-14	VAR(2)	A6	Same as above, but for the second Y variable
		15	PT(2)	A1	
		16	ITEST(2)	I7	
		17-80	VAR(I)	A6	—and so on as for first and second Y variables, until I=NY
			PT(I)	A1	
			ITEST(I)	I1	
	5	1-8	YMIN(1)	F8.0	Origin for first Y variable.
		9-80			Provide the rest of the YMIN vector in the same format as YMIN(1).

Table C-3. Continued.

Group	Card	Column	Name	Format	Description
	6	1-5	NYL(1)	I5	Incrementing index for scaling the first Y variable.
		6-10	NYL(2)	I5	Incrementing index for scaling the second Y variable.
		11-50	NYL(I)	I5	–and so on for as for first and second NYL variables, until I=NY
IIA	See Fig. C 12	80			0 or 9 punch; if punch is 0, subgroup IIB consists one card, I-1; if punch is 9, subgroup IIB consists of cards I-1 to I-6 to control the plots for the next data set.
IIB	See Fig. C-12				same as control card I-1
IIC	See Fig. C-12				(a) Data to be plotted by time for a given station, arranged in any date order for a given station; cards III-5 and III-6, Table C-1 may be used if desired if card I-2 above specifies a format to read up to any NY variables on these cards. (b) If data are to be plotted by station for a given date, then group IIIC cards are arranged by station for a given date. The LL control variable must appear on every data card.


∇∇ REMOTE STOP
DUMMY DATA CARD
9
DATA FOR STATION - 2
CONTROL CARD NO. I-1
DUMMY DATA CARD
0
DATA FOR STATION - 1
SIX CONTROL CARDS FOR PRTPLT
∇N XQT PRTPLT
PRTPLT FORTRAN SOURCE DECK
∇I FOR PRTPLT
1108 RUN CARD
SUBGROUP C
SUBGROUP B
SUBGROUP A
ONE STATION
GROUP II
SUBGROUP C*-FIRST STATION
GROUP I

* Subgroup C, Consists of Data Cards Arranged by (a) Date For a Given Station, or (b) Station For a Given Date.

Figure C-12. Deck set-up for PRTPLT data input.

APPENDIX D

FOURIER SERIES CURVE FITTING

Many natural phenomena characteristically display cyclic patterns of variation, primarily in response to seasonal and diurnal influences. Water temperature and dissolved oxygen concentration, are excellent examples of such cyclic variables.

A Fourier series of the general form

$$Y_i = a + \sum_{j=1}^{n} p_j \cdot \text{Sin}\left(\frac{2\pi \cdot j}{L} \cdot X_i\right)$$

$$+ \sum_{n=1}^{n} q_j \cdot \text{Cos}\left(\frac{2\pi \cdot j}{L} \cdot X_i\right) + \varepsilon_i \quad \text{(D-1)}$$

is well suited to the representation of cyclic phenomena. In this equation,

Y_i = "i th" observed value of the dependent variable

X_i = "i th" value of the cyclic independent variable (time)

L = cyclic period in the independent variable

n = number of terms in the Fourier series model

ε_i = deviation of the "i th" observed value of the dependent variable from the predicted value

p_j and q_j = regression coefficients

This equation is linear in form, if each trigonometric term is considered a coded variable. In this form, linear regression techniques may be employed in fitting the equation to data.

Equation D-1 can be shown to be equivalent to

$$Y_i = a + \sum_{j=1}^{n} C_j \cdot \text{Sin}\left(\frac{2\pi \cdot j}{L} \cdot X_i + A_j\right)$$

$$+ \varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{(D-2)}$$

in which

$$A_j = \text{Tan}^{-1}\left(\frac{p_j}{q_j}\right)$$ = phase shift angle for the "j th" term (radians)

$$C_j = \frac{p_j}{\text{Sin } A_j}$$ = coefficient of the "j th" term

Equation D-1 is rearranged in the form of Equation D-2 to allow greater ease of visualization and to reduce the number of terms. Figure D-1 graphically displays the physical significance of the model parameters C_1, C_2, A_1, and A_2 for a two-term Fourier series model.

For the special case where n = 1, Equation D-2 reduces to a sine-curve. Both single and multiple term Fourier series have been used extensively in this study to represent time variations in cyclic water quality parameters.

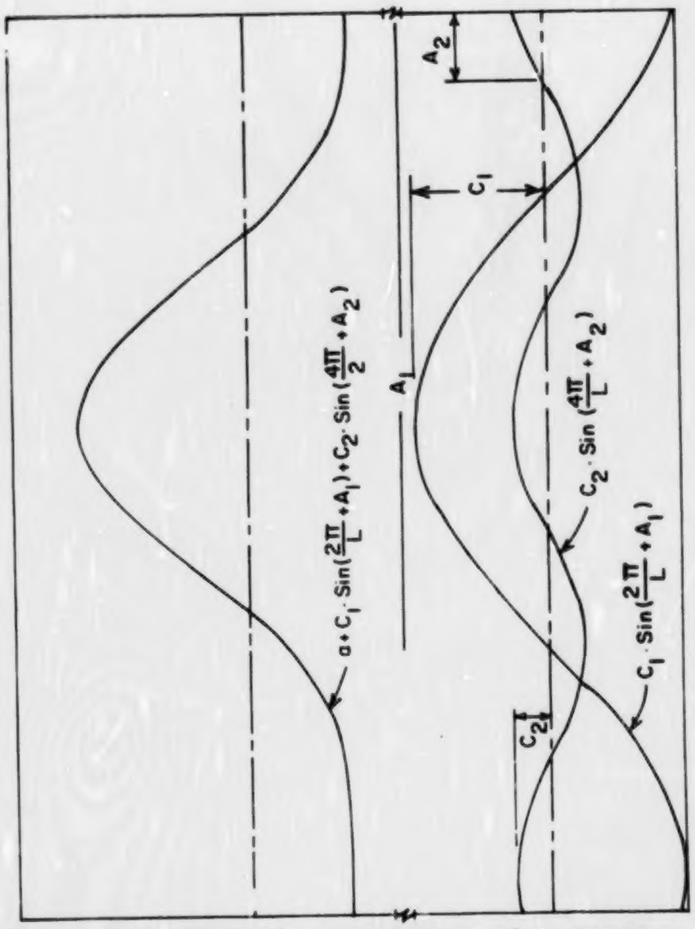

A_2
C_1
$a + C_1 \cdot \text{Sin}\left(\frac{2\pi}{L} + A_1\right) + C_2 \cdot \text{Sin}\left(\frac{4\pi}{2} + A_2\right)$
A_1
$C_2 \cdot \text{Sin}\left(\frac{4\pi}{L} + A_2\right)$
$C_1 \cdot \text{Sin}\left(\frac{2\pi}{L} + A_1\right)$
C_2

Figure D-1. Graphical representation of a two-term Fourier series.

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APPENDIX E

OPERATION OF THE WATER QUALITY SIMULATION MODEL

The water quality simulation model has been developed as a tool, to be used in studying problems of water resources planning and management, as they relate to water quality. The following sections explain procedures involved in using the computer program WAQUAL which is comprised of the individual water quality submodels. Specific instructions for using the program include a discussion of the computational facilities required, directions for specifying simulation options and a description of the data deck requirements.

The Program

Figure E-1 is a listing of the computer program WAQUAL which is the integrated water quality simulation model. This program consists of algorithms for five submodels, listed in Table E-1; the subprogram names, given to each of these submodel algorithms, are also listed. Figure E-1, the WAQUAL program listing, plainly marks each subprogram. The "prior simulation requirements" column lists the subprograms that must be run prior to the one indicated in order to provide the necessary input information to the subprogram in question. The hydrology submodel HYDRO is an independent program described in Appendix G. The output from HYDRO is fed into WAQUAL in the form of punched cards. This independence is not necessary; it is merely the mode of operation found most convenient during development. The "system model" terms connotes HYDRO as a subprogram to WAQUAL, even though they are physically separate program decks.

The program WAQUAL will:

(1) simulate, for the main channel and selected branches, the distance profiles for each month of the year for:
   - (a) mean monthly specific electrical conductance
   - (b) mean monthly stream temperature
   - (c) mean monthly dissolved oxygen

(2) simulate for the main channel and selected branches, the representative monthly diurnal profiles at selected system node points:
   - (a) hourly temperatures over the 24 hour period
   - (b) hourly values of dissolved oxygen over the 24 hour period

A sample of the computer printout is shown in Figure E-3. The stream profiles displayed graphically in Appendix F were plotted from such printout information. The printout, in addition to providing the simulation information from WAQUAL also provides the D.O. simulation in the "percent saturation" form and also repeats information used as input.

Instructions for using this program and further explanations are given in the following sections. These instructions include: (a) discussion of the computer facility required, (b) directions for specifying WAQUAL program options, and (c) definitions of input variables and format specification for each variable.

Computer Requirements

WAQUAL has been programmed in Fortran V for the Univac 1108 electronic digital computer; Figure E-1 is a listing of the program. WAQUAL is dimensioned to handle four branches adjacent to the main stem, with 15 reaches for each branch, and five reservoirs and five effluent discharges. Table E-2 summarizes this capability, which of course can be changed to suit any situation by merely altering the corresponding dimension statements.

Dimensioned in the manner indicated, the program requires approximately 20,000 thirty-two-bit words of memory storage. Complete running time of the 1108 for a one year simulation of the 11 reach Little Bear River system is 28 seconds (14 seconds compilation and 14

Table E-1. WAQUAL subprograms.

Submodel	Subprogram Name	Prior Simulation Requirements
Conductivity	ELCON	HYDRO
Monthly temperature	WATEMP	HYDRO
Diurnal temperature	DITEMP	HYDRO,WATEMP
Monthly D.O.	MDISOX	HYDRO,WATEMP
Diurnal D.O.	DDISOX	HYDRO,WATEMP,DITEMP

Table E-2. Summary of simulation model dimensions.

System component	Number
branches	5[a]
reaches per branch	15
reservoirs	5
M & I discharges	5
control points	5

[a] Including the main stem.

seconds execution). The program is in punched-card form and utilizes punched-card data. Tape storage has not been used.

Without the program list option, the output for a one year simulation run, calling for all five water quality subprograms may be as little as 55 pages or as much as 130 pages, depending on the number of reaches being simulated.

Program Options

The program user has the option of specifying the incorporation or exclusion of any of the five subprograms listed in Table E-1. The electrical conductance and monthly water temperature subprograms may be included or deleted entirely at the discretion of the program user, except when prerequisite to another specified model, as indicated in Table E-1. The procedure for entering model option specifications on punched cards is detailed in Table E-3.

Data Requirements

Data are supplied to the water quality simulation program in punched-card form. Details concerning card formats, variable names, etc., are in Table E-3. The data required may be divided into eight groups. These groups will be discussed in order of their appearance in the data deck.

System definition

The program user must specify the number of branches in the river system being simulated, number of years to be simulated, number of control points, number of reservoirs, number of municipal and industrial waste discharges, mean altitude of the prototype system, model option indicators and location of tributaries, division points between reaches, control points, reservoirs, and waste discharge points.

A convenient coding system has been derived to specify the location of any point on the river system, in terms of the branch on which it is situated and river miles from the mouth of that branch. The format of the location designation is b.xxx. Where "b" is the number of the branch on which the point is situated and "xxx" is the distance from the mouth of the branch in tenths of a mile. For example, the designation 2.062 means that the point is located 6.2 miles from the mouth of branch two.

The serial specification of the months of the simulation year are required for labeling purposes. In the current study the water year, beginning with October first, has been used as the simulation year.

Equilibrium temperature

Here, a constant and coefficient are provided for Equation 19, to define monthly variations in equilibrium stream temperature at every node point in the system. If the monthly water temperature submodel is not a specified option these cards may be omitted.

Diurnal temperature and D.O. model parameters

Next, each of the four parameters (C_1, A_1, C_2, and A_2) for the two-term Fourier series diurnal temperature index submodel (Equation 25) is given for each month of the simulation. Twelve monthly values of each DTI model parameter are entered on one card. The four cards are arranged in the order indicated above. This is followed by the parameters for the diurnal dissolved oxygen index model (Equation 53) for each month. If either or both of the diurnal models are excluded from the simulation, the parameter cards pertaining to that model may be omitted.

Hydraulic relationships

Multipliers and exponents for Equation 8 are provided here to define the relationships between flow rate and cross sectional area of flow. Coefficients and exponents must also be provided for the exponential relationship similar to Equation 8 for mean depth of flow.

Monthly water quality submodel parameters

Each of the water quality submodels requires a reach-by-reach definition of input and transport parameters. The data to be read in consists of submodel parameters for conductivity, monthly temperature, monthly BOD, and monthly D.O., in that order, for every reach in the system. The input format calls for reading the cards in sets, beginning with the first set, corresponding to lowest reach on the main stem, proceeding to the highest reach on the main stem, then from the lowest reach on the lowest tributary branch in the system to the most upstream reach on that branch, followed by the lowest reach on the next tributary upstream, etc., finally ending with the highest reach on the most upstream tributary of the hydrologic system. Each set consists of four cards, completely defining the input and in-transit models for that reach. The data input requirements for a typical river reach are discussed individually below.

Electrical conductance. Because electrical conductance is essentially a conservative quality parameter, it is necessary only to define input model parameters. The natural surface inflow model requires a multiplier, a, and an exponent, b, relating conductivity to rate of flow, in accordance with Equation 11. Groundwater conductance is assumed constant over time for any given reach. This conductance is read in here. A two-term Fourier series representation has been provided for the simulation of conductivity of surface irrigation return flows. The mean annual conductance, multipliers, C, and phase shifts, A, are included at this point in the data deck for each reach. If the conductivity model is not called, the above data are omitted.

Temperature. Natural surface inflow temperatures are related to mean monthly atmospheric temperature by Equation 19. The constant and coefficient for this relationship must be provided via data input.

Monthly groundwater inflow temperatures are simulated by Equation 18, which is a simple sine-curve representation of the annual cycle of groundwater temperature. This equation requires the mean annual temperature (°C), a multiplier, C, and a phase angle shift, A (radians).

The temperature of surface irrigation return flow is assumed to be related to mean monthly atmospheric temperature (Equation 19). Again, the constant and multiplier are provided as data input. The heat exchange coefficient has been assumed to be related exponentially to the rate of combined inflow to the reach (Equation 21). A multiplier and an exponent are required for each reach.

None of the temperature information is to be included if the monthly water temperature model is not incorporated in the simulation.

BOD and D.O. In simulating BOD and dissolved oxygen changes in a reach, the first step is to approximate the BOD and D.O. concentration and deoxygenation rate constant for each component of inflow. The BOD of natural surface inflows are represented in Equation 50 as simple sine-curve. Each characteristic element of this relationship ($\overline{BOD}$, C, and A) must be defined. The deoxygenation rate constant (base 10, day^{-1}), given at this deck location, is assumed to be constant throughout the year. BOD of surface irrigation return flows and groundwater inflows and the deoxygenation rate constant for these components are assumed constant through the year and are simply read in as mean annual values. Provision is made in the program for decreasing the deoxygenation rate constant of Equation 32 as organic material stabilization proceeds. The amount of decrementation in deoxygenation rate constant within the reach (base 10, day^{-1}) must be specified.

Other BOD information required for Equation 32 is: scour rate constant (mg/l/day) deposition rate constant (base 10, day^{-1}) for organics, difference between laboratory and river deoxygenation rate constants (base 10, day^{-1}), anaerobic decay rate constant for benthic deposits (base 10, day^{-1}), and areal BOD of stream bottom deposits (gm/sq. meter). It should be emphasized, here, that Equation 32 has been programmed on the computer using base 10, rather than base e exponents.

Annual cycles in dissolved oxygen concentrations of natural surface inflow and irrigation return are simulated by a two-term Fourier series (Equation 49). Again, mean annual values, multipliers, C, and phase shifts, A, must be provided for each of these models. A sine-curve model, similar to Equation 49, simulates D.O. concentrations in groundwater inflow, requiring mean annual temperature, a coefficient, C, and phase shift, A, as input. All of these data are omitted if the monthly D.O. modeling option is not specified.

Finally, for the case where diurnal variations are to be simulated, an average productivity constant (pf in Equation 55) is entered for each month of the year. These factors are determined by a process of trial and error during model development in which diurnal D.O. model results are altered by changing pf until a satisfactory approximation of the observed annual pattern for diurnal stream D.O. is obtained.

Reservoir data

If reservoirs are included in the hydrologic system to be simulated, the following modeling data must be obtained, beginning with the most downstream reservoir on the main stem and ending with the most upstream reservoir on the highest tributary stream:

1. Conductivity of water in storage at the beginning of the simulation
2. Volume of water in storage at the beginning of the simulation (acre-feet)
3. Reservoir storage capacity (acre-feet)
4. Mean annual temperature (°C), coefficients, C, and phase shifts, A, for a four-term Fourier series representation of the annual discharge temperature cycle (°C)
5. Mean annual BOD (mg/l), coefficient, C, and phase shift, A, for sine-curve representation (Equation 50) of the annual cycle in BOD of the reservoir discharge stream
6. Mean annual D.O. (mg/l), coefficient, C, and phase shift, A, for sine-curve representation (Equation 51) of the annual cycle in discharge stream dissolved oxygen concentration

If any monthly water quality submodel is not included in the simulation, reservoir data relating to that submodel may be entered on the data card as zeroes.

Atmospheric temperature

If monthly stream temperatures are to be simulated, mean monthly atmospheric temperatures (F) must be provided for each month of the year.

Monthly data

For every month of simulation a quantitative and qualitative description of each municipal-industrial waste discharge must be provided as an input to the simulation program. The water quality simulation model employs the results of a reach-by-reach hydrologic simulation model, in punched card form, to define the hydrologic inputs to the system.

The data input format calls for all municipal and industrial (M & I) waste discharge data for any given month to precede the system hydrologic data for that month. The data required in each of these categories are discussed briefly in the following paragraphs.

Municipal and industrial waste discharges. Monthly definition of M & I waste discharge flow and quality characteristics consists of the following:

1. Mean monthly rate of discharge (cfs)
2. Mean monthly conductivity of the waste stream (micro-mhos/cm)
3. Mean monthly waste stream temperature (°C)
4. Mean monthly waste stream D.O. concentration (mg/l)
5. Mean monthly waste stream BOD (mg/l)
6. Deoxygenation rate constant (base 10, day^{-1})
7. Hourly diurnal discharge indexes
8. Hourly diurnal temperature indexes
9. Hourly diurnal D.O. indexes
10. Hourly diurnal BOD indexes

If any of the monthly quality submodels are not to be included in the simulation, the parameters relating to this submodel may be punched as zeroes. If any of the diurnal submodels are to be excluded from the simulation, the associated hourly diurnal index card should be omitted. This information must be provided for all effluent discharge points in the system prior to the hydrologic data.

Hydrologic data. Monthly hydrologic data consists of a reach-by-reach tabulation of natural surface inflow (cfs), surface irrigation return flow (cfs), groundwater inflow (cfs) and diversions (cfs). For reaches representing surface impoundments, the above data are supplemented by net direct precipitation (cfs), reservoir storage at the end of the month (acre-feet), and reservoir depth above the discharge inlet (ft.). Net direct precipitation is defined as precipitation falling directly on the water surface less evaporation loss.

As shown in Table E-3, hydrologic data for one reach is presented on a single card. The hydrologic data must be assembled in the order of reach simulation, that is, beginning with the most upstream reach on the main stem and proceeding downstream to the point of confluence with the most upstream tributary, shifting to the upper end of that branch, proceeding to the reach ending at its mouth, then shifting to the main stem reach to which that branch is tributary and proceeding on downstream until the next tributary branch is encountered or until the last reach on the main stem has been simulated.

The hydrologic data input is provided on punched cards generated by the hydrology submodel. The hydrologic data must be integrated into the data deck for the water quality simulation in the manner described above. Figure E-2 is a listing of the data deck, as it was assembled for a one month (October, 1968) simulation of the Little Bear River system.

NOT REPRODUCIBLE

```
C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
C                                                                             C
C                               W A Q U A L                                   C
C                                                                             C
C      WATER QUALITY SIMULATION MODEL                                         C
C                                                                             C
C      SUBMODELS INCLUDED IN THE MODEL                                        C
C           MONTHLY ELECTRICAL CONDUCTANCE   (FLCON)                          C
C           MONTHLY WATER TEMPERATURE   (WATEMP)                              C
C           DIURNAL WATER TEMPERATURE   (DITEMP)                              C
C           MONTHLY DISSOLVED OXYGEN   (MDISOX)                               C
C           DIURNAL DISSOLVED OXYGEN   (DDISOX)                               C
C                                                                             C
C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
```

Figure E-1. WAQUAL computer program listing.

NOT REPRODUCIBLE

```
C IS REACH [illegible] A RESERVOIR
      DO 610 IRR=1,NRES
      IF (RCHLOC(I,J).EQ.RESLOC(IRR)) GO TO 615
  610 CONTINUE
  611 CONTINUE
      [illegible]
      GO TO 650
  615 CONTINUE
      IF ([illegible]) GO TO 625
  620 [illegible]
      [illegible]
      [illegible]
      GO TO 640
  625 [illegible]
      GO TO 630
  645 [illegible]
      [illegible]
  650 CONTINUE
      [illegible]
  699 CONTINUE
      IF ([illegible]) GO TO [illegible]
C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
C                                                                     C
C                           [illegible]                               C
C                                                                     C
C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
      [illegible]
C IS THIS REACH A RESERVOIR
      DO 630 IRR=1,NRES
      IF (RCHLOC(I,J).EQ.RESLOC(IRR)) GO TO 640
  630 CONTINUE
  635 CONTINUE
      [illegible]
      GO TO 650
  640 CONTINUE
      [illegible]
  650 CONTINUE
  699 CONTINUE
      IF ([illegible]) GO TO [illegible]
C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
C                                                                     C
C                           [illegible]                               C
C                                                                     C
C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
      IF (NRES.EQ.0) GO TO [illegible]
C IS THIS REACH A RESERVOIR
      DO 601 IRR=1,NRES
      IF (RCHLOC(I,J).EQ.RESLOC(IRR)) GO TO 650
  601 CONTINUE
  [illegible] CONTINUE
C C [illegible]
      [illegible]
C C [illegible]
      [illegible]

      DT(I,J,MT) = DTEX+DTE9
  675 CONTINUE
      GO TO 689
  650 CONTINUE
C IS THE RESERVOIR SPILLING
      IF ([illegible]) GO TO 691
C IS RESERVOIR DEPTH GREATER THAN 20 FEET
      IF (DD(IR).GT.20.) GO TO 655
C RESERVOIR DEPTH IS LESS THAN 20 FEET
  651 CONTINUE
      DO 651 MT=1,24
      DT(I,J,MT) = T(I,J)+DT(IR)(IR)
  651 CONTINUE
      GO TO 689
  655 CONTINUE
C RESERVOIR DEPTH IS GREATER THAN 20 FEET
      DO 657 MT=1,24
      DT(I,J,MT) = T(I,J)
  657 CONTINUE
  689 DO 690 JT=1,24
      IF (DT(I,J,JT).LT.0.) GO TO 691
  690 CONTINUE
      GO TO 699
  691 SMT = 0.
      DO 692 MT=1,24
      IF (DT(I,J,MT).LT.0.) DT(I,J,MT) = 0.
  692 SMT = SMT+DT(I,J,MT)
      T(I,J) = SMT/24.
  699 CONTINUE
      IF (IW.NE.1) GO TO 799
C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
C                                                                     C
C                           [illegible]                               C
C                                                                     C
C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
      CS = SATCON(PRES,T(I,J))
      [illegible]
      [illegible]
     1[illegible]
     2[illegible]
      [illegible]
     1[illegible]
      [illegible]
     1[illegible]
      [illegible]
C C COMPUTE SATURATION CONCENTRATION OF DISSOLVED OXYGEN
      [illegible]
     1[illegible]
     2)
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      IF (NRES.EQ.0) GO TO 711
      DO 701 IR=1,NRES
      IF (RCHLOC(I,J).EQ.RESLOC(IR)) GO TO 710
  701 CONTINUE
  711 CONTINUE
C C THIS REACH IS NOT A RESERVOIR
      CS1 = SATCON(PRES,TIN(I,J))
      WM = .305*W(I,J)
C C MEAN VELOCITY IN F.E.T/SEC.
      VEL = Q(N(I,J)/A(I,J)
C C TIME OF TRAVEL (DAYS)
      TT = RCHL(I,J)/(VEL*86400.)
      TAV = (TIN(I,J)+T(I,J))/2.0
      DELT = TAV-20.0
      IF (TAV.GE.20.0) GO TO 716
      THET = 1.065-.0012*(TAV-5.0)
      GO TO 717
  716 THET = 1.047
  717 CONTINUE
      CORT = THET**(TAV-20.0)
      R1IN = CORT*R1IN
      TCAR = 1.0[illegible]**DELT
C C REAERATION CONSTANT (BASE 10)
      [illegible]
      [illegible]
C C OXYGEN DEFICIT IN INFLOW TO REACH
      DA = CS1-DOIN(I,J)
      IF (DA.LT.0.) DA = 0.
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
C C OXYGEN DEFICIT IN OUTFLOW FROM THIS REACH
      [illegible]
     1[illegible]
C C DISSOLVED OXYGEN IN OUTFLOW FROM THIS REACH
      DO(I,J) = CS-[illegible]
C C B.O.D. REMAINING IN OUTFLOW FROM THIS REACH
      IF ([illegible]) GO TO 703
      [illegible]
      GO TO 704
  703 BOD(I,J) = [illegible]
  704 CONTINUE
      IF ([illegible]) GO TO 705
C C SCOUR IS OCCURRING IN THIS REACH
      [illegible]
     1[illegible]
      GO TO 739
  705 CONTINUE
C C NO SCOUR THIS REACH
      [illegible]
     1[illegible]
      [illegible]
      GO TO 739
  710 CONTINUE
C C THIS REACH IS A RESERVOIR
      [illegible]
      [illegible]
      [illegible]
  739 BOD(I,J) = [illegible]
      [illegible]
  799 CONTINUE
      IF ([illegible]) GO TO [illegible]
C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
C                                                                     C
C                           [illegible]                               C
C                                                                     C
C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C
      IF (NRES.EQ.0) GO TO 815
C C IS THIS REACH A RESERVOIR
      DO 801 IR=1,NRES
      IF (RCHLOC(I,J).EQ.RESLOC(IR)) GO TO 821
  801 CONTINUE
C C THIS REACH IS NOT A RESERVOIR
  815 CONTINUE
```

Figure E-1. Continued.

NOT REPRODUCIBLE

```
C  C  COMPUTE DIURNAL D.O. DISTRIBUTION AT REACH "I" OF BRANCH"J".
      DO 820 MTI=1,24
      MT = MTI+MTT
  823 IF (MT.GT.24) GO TO 824
      GO TO 825
  824 MT = MT-24
      GO TO 823
  825 CONTINUE
C  C  COMPUTE THE SATURATION CONCENTRATION OF D.O.
      CS = SATCON(PRES,DTI(I,J,MT))
      CSI = SATCON(PRES,DTRFG(MT))
      IF (QI(I-1,J).LE.0.) GO TO 804
      TRODI = QI(I-1,J)*DRODI(I-1,J,MT))
      TRII = TRODI*RI(I-1,J)
      TDOI = QI(I-1,J)*DDOI(I-1,J,MT))
      GO TO 805
  804 TRODI = 0.0
      TRII = 0.0
      TDOI = 0.0
  805 IF (QS(I,J).LE.0.) GO TO 806
      DDOS = DOS(I,J)*DOINS(MT))
      TRODS = QS(I,J)*RODS(I,J)
      TRIS = TRODS*RIS(I,J)
      TDOS = QS(I,J)*DDOS
      GO TO 807
  806 TRODS = 0.0
      TRIS = 0.0
      TDOS = 0.0
  807 IF (QIR(I,J).LE.0.) GO TO 808
      DDOIR = DOIR(I,J)*DOINDI(MT))
      TRODIR = QIR(I,J)*RODIR(I,J)
      TRIIR = TRODIR*RIIR(I,J)
      TDOIR = QIR(I,J)*DDOIR
      GO TO 809
  808 TRODIR = 0.0
      TRIIR = 0.0
      TDOIR = 0.0
  809 CONTINUE
      IF (NEFF.EQ.0) GO TO 814
      DO 802 IFF=1,NEFF
      IF (RCHLOC(I-1,J).EQ.EFLOC(IFF)) GO TO 818
  802 CONTINUE
      DOIN = QIN(I,J)
      GO TO 819
  818 DDOEF = DOEF(I,J)*DOEFF(IFF,MT))
      DRODEF = RODEF(I,J)*RODEFI(IFF,MT))
      TDOEF = QEF(I,J)*DDOEF*QEFF(IFF,MT))
      TRODEF = QEF(I,J)*DRODEF*QEFF(IFF,MT))
      TRIEF = TRODEF*RIEF(I,J)
      DOIN = QIN(I,J)-QEF(I,J)*(1.-QEFF(IFF,MT)))
      GO TO 803
  814 TRODEF = 0.0
      TRIEF = 0.0
      TDOEF = 0.0
  803 IF (QGI(I,J).LE.0.) GO TO 810
      TDOGI = QGI(I,J)*DOGI(I,J)
      TRODGI = QGI(I,J)*RODGI(I,J)
      TRIGI = TRODGI*RIGI(I,J)
      GO TO 811
  810 TDOGI = 0.0
      TRODGI = 0.0
      TRIGI = 0.0
  811 IF (QRR(I,J).LE.0.) GO TO 812
      TDORR = QRR(I,J)*DORR(I,J,MT))
      TRODRR = QRR(I,J)*DRODRR(I,J,MT))
      TRIRR = TRODRR*RIRR(I,J)
      GO TO 813
  812 TDORR = 0.0
      TRODRR = 0.0
      TRIRR = 0.0
  813 CONTINUE
      DOI = (TDOI+TDOS+TDOIR+TDOEF+TDOGI+TDORR)/DOIN
      RODI = (TRODI+TRODS+TRODIR+TRODEF+TRODGI+TRODRR)/DOIN
      RIIN = (TRII+TRIS+TRIIR+TRIGI+TRIEF+TRIRR)/(RODI*DOIN)
      TAV = (CTRFG(MT)+DTI(I,J,MT))/2.0
      IF (TAV.GE.20.5) GO TO 816
      THET = 1.065-.0012*(TAV-5.0)
      GO TO 817
  816 THET = 1.047
  817 CONTINUE
      COFT = THET**(TAV-20.0)
      RIIN = COFT*RIIN
      DR = RD(I,J)*RIIN*RT(I,J)
      DELT = TAV-20.0
      TCMR = 1.016**DELT
C  C  REAERATION CONSTANT (BASE 10)
      RR2 = R2(I,J)*TCMR
      FR1 = EXP(-RR*2.3*TT)
      FR2 = EXP(-RR2*2.3*TT)
      COF1 = (RIIN*RR(I,J)*(1.0*RT(I,J))/RR)/(RR2-RR)
      COF2 = RR(I,J)/(RR2-RR(I,J))
C  C  COMPUTE DISSOLVED OXYGEN IN OUTFLOW FROM THIS REACH
      DA = CSI-DOI
      IF (DA.LT.0.) DA = 0.
      DR = DA*FR2+COF1*(RODI-RP(I,J)/(2.3*DR))*(FR1-FR2)+COF2*
     1(RODI(I,J)/RR*RR(I,J)/(2.3)*RR(I,J))*(1.0-FR2)
      PROD = PCON(I,J,MT)*(DOINC(MT)-1.0)
      DOD(I,J,MT) = CS-DR+PROD
      IF(DOD(I,J,MT).LT.0.) GO TO 833
      DOD(I,J,MT) = (RODI-RP(I,J)/(2.3*DR)*FR1*RP(I,J)/(2.3)*DR)
      GO TO 831
  833 DOD(I,J,MT) = 0.0
  831 CONTINUE
  820 CONTINUE
      GO TO 838
  821 CONTINUE
C  C  THIS REACH IS A RESERVOIR
      DO 832 MT=1,24
  832 DOD(I,J,MT) = DO(I,J)
  838 CONTINUE
C  IS THE LOWER END OF THIS REACH A CONTROL POINT
      DO 21 ID=1,NCPTS
      IF (RCHLOC(I,J).EQ.CPTLOC(ID)) GO TO 22
   21 CONTINUE
      GO TO 23
   22 CONTINUE
      QCPT(ID,K) = Q(I,J)
      IF (IW.EQ.1) GO TO 17
      GO TO 18
   17 DOCPT(ID,K) = DO(I,J)
      RODCPT(ID,K) = ROD(I,J)
   18 CONTINUE
      IF (IV.EQ.1) ECCPT(ID,K) = EC(I,J)
      IF (IT.EQ.1) TCPT(ID,K) = T(I,J)
      IF (IT.EQ.1) GO TO 16
      GO TO 23
   16 DO 27 MT=1,24
      DTCPT(ID,MT) = DT(I,J,MT)
   27 CONTINUE
      IF (IW.NE.1) GO TO 19
      DO 18 MT=1,24
      DOSH(ID,MT) = DOD(I,J,MT)
   18 CONTINUE
   19 CONTINUE
   23 CONTINUE
C  ARE WE ON THE MAIN STEM
      IF (J.EQ.1) GO TO 90
C  IS THIS THE LAST REACH ON THIS BRANCH
      IF(I.EQ.1) GO TO 75
      I = I-1
      GO TO 20
   75 QQR(I1,J1) = Q(I,J)
      J1 = J
      IF (IT.EQ.1) TRR(I1,J1) = T(I,J)
      IF (IV.EQ.1) ECRR(I1,J1) = EC(I,J)
      IF (IW.NE.1) GO TO 55
      DORR(I1,J1) = DO(I,J)
      RODRR(I1,J1) = ROD(I,J)
      RIRR(I1,J1) = RI(I,J)
   55 I = I1
      J = 1
      L = L-1
      GO TO 20
   90 CONTINUE
C  IS THIS THE LAST REACH ON THE MAIN STEM
      IF(I.EQ.1) GO TO 80
      I = I-1
      GO TO 10
   80 CONTINUE
C OUTPUT PROFILE OF EACH PARAMETER
      WRITE (6,111)
  111 FORMAT(1H1,28X,*MONTHLY STREAM FLOW PROFILE*)
      WRITE (6,112) N
  112 FORMAT(21H0YEAR OF SIMULATION = ,I7)
      WRITE (6,113) AMO(K)
  113 FORMAT(18H MONTH OF YEAR = ,A6)
      WRITE (6,114)
  114 FORMAT(1H0,18X,*LOCATION               I--------INPUTS--------I  I
     1--OUTPUTS-I*)
      WRITE (6,115)
  115 FORMAT(1H ,* BRANCH REACH  FROM    TO    STRM  EFFC IR RET GW   BRAN
     1CH  REI    STRM    FLOW*)
      WRITE (6,116)
  116 FORMAT(1H ,22X,*TO IN    QS    QIR   QGI   QRR   QEF    Q OUT   QD*/)
      DO 41 JE=1,NPR
      NF=NLRCH(JE)-NRRCH(JE)+1
      DO 42 IEI=1,NF
      IF = NE-IEI+1
      RLOC2 = (RCHLOC(IF,JE)-JE)*100.
      RLOC1 = (RCHLOC(IF+1,JE)-JE)*100.
      IC=IF-1+NRRCH(JE)
      WRITE (6,117)JE,IC,RLOC2,RLOC1,QIN(IF,JE),QS(IF,JE),QIR(IF,JE),
     1QGI(IF,JE),QRR(IF,JE),QEF(IF,JE),Q(IF,JE),QD(IF,JE)
  117 FORMAT (1H ,2I6,2F7.1,6(1X,F5.1),1X,F5.1,1X,F5.1)
   42 CONTINUE
   41 CONTINUE
      IF (IV.NE.1) GO TO 76
      WRITE (6,160)
  160 FORMAT (1H0///21X,*MONTHLY ELECTRICAL CONDUCTANCE PROFILE*)
      WRITE (6,112) N
      WRITE (6,113) AMO(K)
      WRITE (6,114)
      WRITE (6,115)
      WRITE (6,161)
  161 FORMAT (1H ,22X,*EC IN  ECS  ECIR  ECGI   ECRR  ECEF   EC OUT  ECD
     1*/)
      DO 43 JE=1,NPR
      NE=NLRCH(JE)-NRRCH(JE)+1
      DO 43 IEI=1,NF
      IE=NE-IEI+1
      IF(QI(IE,JE).LE.0.) ECI(IE,JE)=9999999.
      IF(QS(IE,JE).LE.0.) ECS(IE,JE)=999999.
      IF(QIR(IE,JE).LE.0.) ECIR(IE,JE)=9999999.
      IF(QRR(IE,JE).LE.0.)  ECRR(IE,JE)=9999999.
      IF(QEF(IE,JE).LE.0.)  ECEF(IE,JE)=9999999.
      IF(QGI(IE,JE).LE.0.)  ECGI(IE,JE)=9999999.
      IF(QD(IE,JE).LE.0.) ECD(IE,JE)=999999.
      RLOC2=(RCHLOC(IE,JE)-JE)*100.
      RLOC1=(RCHLOC(IE+1,JE)-JE)*100.
      IC=IE-1+NRRCH(JE)
      WRITE(6,162) JE,IC,RLOC2,RLOC1,ECIN(IE,JE),ECS(IE,JE),ECIR(IE,JE),
     1ECGI(IE,JE),ECRR(IE,JE),ECEF(IE,JE),EC(IE,JE),ECD(IE,JE)
  162 FORMAT (1H ,2I6,2F7.1,6(1X,F5.0),1X,F5.0,1X,F5.0)
   43 CONTINUE
   76 CONTINUE
      IF (IT.NE.1) GO TO 77
      WRITE (6,170)
  170 FORMAT (1H1,29X,*MONTHLY WATER TEMPERATURE PROFILE*)
      WRITE (6,112) N
      WRITE (6,113) AMO(K)
      WRITE (6,114)
      WRITE (6,115)
      WRITE (6,171)
  171 FORMAT(1H ,22X,*T IN    TS    TIR    TGI    TRR    TEF     T OUT   TD*/)
      DO 44 JE=1,NPR
      NE=NLRCH(JE)-NRRCH(JE)+1
      DO 44 IEI=1,NE
      IE=NE-IEI+1
      IF(QI(IE,JE).LE.0.) TI(IE,JE)=9999999.
      IF(QS(IE,JE).LE.0.) TS(IE,JE)=9999999.
      IF (QIR(IE,JE).LE.0.) TIR(IE,JE)=9999999.
      IF(QRR(IE,JE).LE.0.) TRR(IE,JE)=9999999.
      IF(QEF(IE,JE).LE.0.)  TEF(IE,JE)=9999999.
      IF(QGI(IE,JE).LE.0.)  TGI(IE,JE)=9999999.
      TO(IE,JE) = T(IE,JE)
      IF(QD(IE,JE).LE.0.) TD(IE,JE)=9999999.
      RLOC2=(RCHLOC(IE,JE)-JE)*100.
      RLOC1=(RCHLOC(IE+1,JE)-JE)*100.
      IC=IE-1+NRRCH(JE)
      WRITE (6,117)JE,IC,RLOC2,RLOC1,TIN(IE,JE),TS(IE,JE),TIR(IE,JE),
     1TGI(IE,JE),TRR(IE,JE),TEF(IE,JE),TO(IE,JE),TD(IE,JE)
   44 CONTINUE
   77 CONTINUE
      IF (IW.NE.1) GO TO 78
C  C OUTPUT SPATIAL PROFILES OF R.O.D. AND D.O. FOR THE MONTH
      WRITE (6,155)
  155 FORMAT (1H0//18X,*MONTHLY D.O. PERCENT SATURATION PROFILE*)
      WRITE (6,112) N
      WRITE (6,113) AMO(K)
      WRITE (6,114)
      WRITE(6,115)
      WRITE (6,156)
  156 FORMAT (1H ,22X,*PS IN   PSS  PSIR  PSGI   PSRR  PSEF   PS OUT  PSD
     1*)
      DO 56 JE=1,NPR
      NF = NLRCH(JE)-NRRCH(JE)+1
      DO 56 IEI=1,NF
      IE = NE-IEI+1
  210 CS = SATCON(PRES,TIN(IE,JE))
      PSIN = 100.*DOIN(IE,JE)/CS
      IF(QI(IE,JE).GT.0.) GO TO 51
      PS = 9999999.
      GO TO 50
   51 CS = SATCON(PRES,TI(IE,JE))
```

Figure E-1. Continued.

NOT REPRODUCIBLE

Figure E-1. Continued.

```
    2    1    5    2    2 4500    1    1    1    1    1
    1    9    0    1    2    6
 1175 1120 1167 1105 1213 1224 1257 1270 1301 1319
 2000 2010 2013
 1125 1120 1224 1257 1301
 1167 1301
 1120 1211
OCT   NOV   DEC   JAN   FEB   MARCH APRIL MAY   JUNE  JULY  AUG   SEPT
 -120 -120 -110 -100 -100 -100 -100 -100 -100 -100
  510  510  460  440  420  400  400  400  400  400
 -100 -100 -100
  400  400  400
   160   230   420   530   514   357   227   139   191   300   281   191
  3333  3511  3647  3860  3934  3896  3618  3463  3257  3037  3077  3216
   039   083   179   235   223   140   067   020   042   088   082   046
  -476  -161   000    03   039   547  -536  -731  -875 -1156  -747  -419
   090   089   083   049   028   037   093   139   167   167   128   095
  4028  4366  4474  4717  4873  4796  4529  4287  4241  4379  4530  4539
   050   050   044   027   016   015   029   037   042   044   040   042
   428   717   931  1132  1706  1142   867   566   235  -017  -010   177
    2    6   20    7
  350    0  620  650
  -25  250  105   20 2230       -100  450    3    0
   20   10 -900   15   45   13    0    0    2    0    0    4    0    0
   85 1500 -400    0    0   70 1800 -400    0    0   70 3000 -400
   70   90   90  170  130  120   80   50   45   50   70   70
  400    0  620  650
  -25  250  105   20 2230       -100  450    3    0
   20   10 -900   15   45   13    0    0    2    0    0    4    0    0
   85 1500 -400    0    0   70 1800 -400    0    0   70 3000 -400
  110  115  110  130  155  150  120  100  100  100  105  105
  400    0  600  650
  -25  250  105   20 2230       -100  450    3    0
   20   10 -900   15   45   13    0    0    2    0    0    4    0    0
   85 1500 -400    0    0   70 1800 -400    0    0   70 3000 -400
  105  110  110  130  130  130  105   80   80  105  105  105
  400    0  550  650
  -25  250  105   20 2230       -100  450    3    0
   20   10 -900   15   45   13    0    0    2    0    0    4    0    0
   85 1500 -400    0    0   70 1800 -400    0    0   70 2000 -400
  100  100   90  110  135  135   70   40   30   85   85   85
  350    0  550  650
  -35  260  105   20 2230       -100  450    3    0
   20   10 -900   15   45   13    0    0    2    0    0    4    0    0
   85 1500 -400    0    0   70 1800 -400    0    0   70 1500 -400
  100  100   85  105  130  125   60   30   30   85   80   80
  350    0  500  650
  -35  260  105   20 2230       -100  450    3    0
   20   10 -900   15   45   13    0    0    2    0    0    4    0    0
   85 1500 -400    0    0   70 1800 -400    3    0   70 1500 -400
   75   90   75   95  170  115   60   40   30   75   75   80
```

```
  300    0  500  650
  -40  280  105   20 2230       -110  480    3    0
   20   10 -900   15   45   13    0    0    2    0    0    4    0    0
   85 1500 -400    0    0   70 1800 -400    0    0   70 1500 -400
   65   80   65   85  110  105   60   30   30   65   60   60
  300    0  500  650
  -50  300  105   20 2230       -110  480    3    0
   20   10 -900   15   45   13    0    0    2    0    0    4    0    0
   85 1500 -400    0    0   70 1800 -400    0    0   70 1500 -400
   55   65   55   75  100   95   55   20   30   50   50   50
  490 -114  500  650
  -50  300  105   20 2230       -110  480    3    0
   18   10 -930   15   45   13    0    0    2    0    0    4    0    0
   85 1500 -400    0    0   70 1800 -400    0    0   70 1500 -400
   45   55   45   65   90   85   45   30   30   40   40   40
    2    6   20    7
  300    0  500  650
  -45  290  105   20 2230       -110  480    3    0
   20   10 -900   15   45   13    0    0    2    0    0    4    0    0
   87 1500 -320    0    0   70 1800 -400    0    0   70 1500 -400
   45   50   50   70   90   85   50   35   35   45   45   45
  810 -246  500  650
  -45  290  105   20 2230       -100  480    3    0
   18   10-1000   15   45   13    0    0    2    0    0    4    0    0
   87 1500 -320    0    0   70 1600 -400    0    0   70 1500 -400
   40   45   45   65   90   85   45   30   30   40   40   40
  380 10610 35200   83   53    8   27   20 2304 1809 1449 3838
   26    9-1272   86   30-1243
  300  3440 32800   83   53    8   27   20 2304 1809 1449 3838
   15    9-1272   86   10-1243
  499  396  215  197  294  403  417  543  627  729  661  590
  100  565  110   78   52   15
100100100100100100100100100100100100100100100100100100100100100100100100
 93 91 90 89 88 86 86 86 88 91 96101107112117119120118114110105101 97 95
100100100100100100100100100100100100100100100100100100100100100100100100
 75 70 65 60 58 58 60 65 90180195200180160130115106100 96 93 90 86 83 80
  300  466   96   63  144   15
100100100100100100100100100100100100100100100100100100100100100100100100
 93 91 90 89 88 86 86 86 88 91 96101107112117119120118114110105101 97 95
100100100100100100100100100100100100100100100100100100100100100100100100
100100100100100100100100100100100100100100100100100100100100100100100100
  103    0   47    0   -1  3818  795
    5    0   31    0
    2    0    9    0
  290    0    0    0
    1    0    6    0
   17    0   31  250
    6    0   20    0
    5    0   19    0
    0    0   24  104   -1 10520  600
    5    0  116    0
    0    0   17    0
```

Figure E-2. Sample WAQUAL data deck.

NOT REPRODUCIBLE

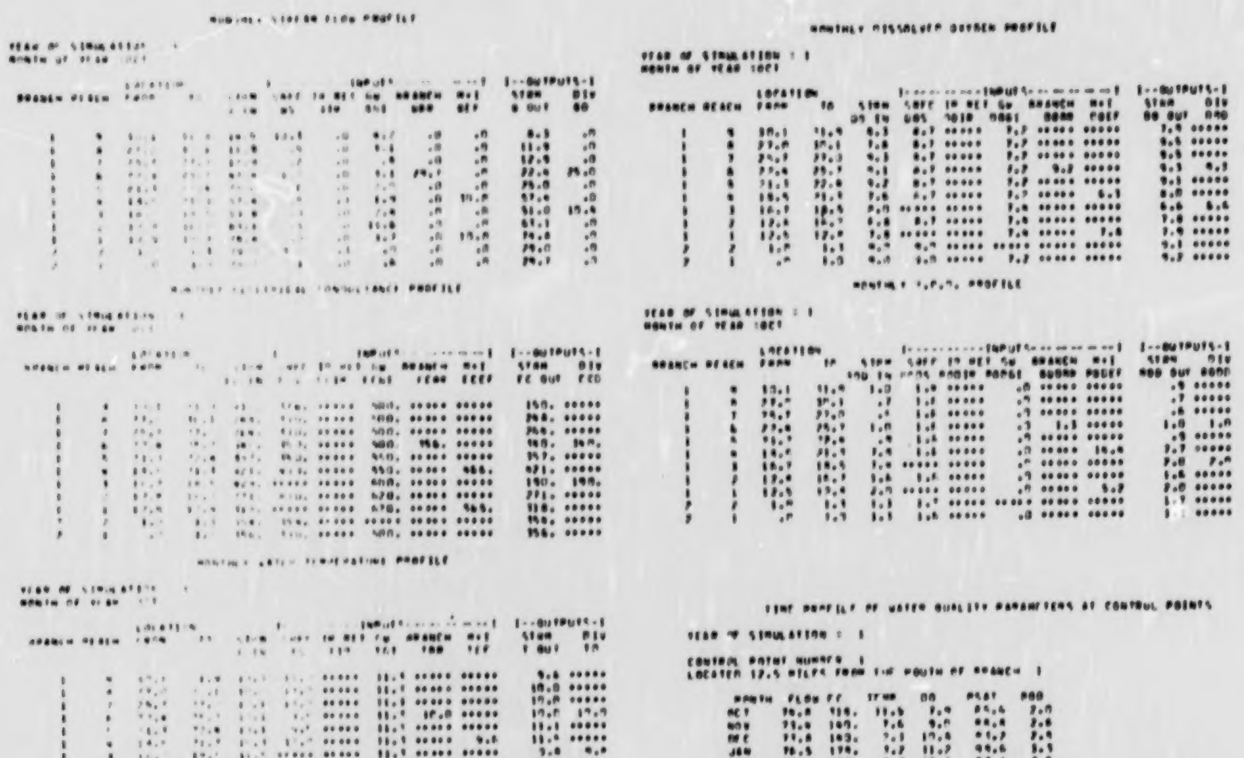


Figure E-3. Sample WAQUAL output.

Table E-3. WAQUAL simulation model data deck set-up.

Card	Col	Format	Variable Name	Definition	Remarks
1	1-5	I5	NBR	No. of branches in the system	not more than 5
	6-10	I5	NYR	No. of years to be simulated	
	11-15	I5	NCPTS	No. of control points designated	not more than 5
	16-20	I5	NRES	No. of reservoirs	not more than 5
	21-25	I5	NEF	No. of M & I effluent discharges	not more than 5
	26-30	I5	ALT	Mean altitude of the hydrologic system	
	31-35	I5	IV	Conductivity model option indicator	0 = No; 1 = Yes
	36-40	I5	IW	Monthly D.O. model option indicator	0 = No; 1 = Yes
	41-45	I5	IX	Diurnal D.O. model option indicator	0 = No; 1 = Yes
	46-50	I5	IY	Monthly water temperature model option indicator	0 = No; 1 = Yes
	51-55	I5	IZ	Diurnal water temperature model option indicator	0 = No; 1 = Yes
2	1-4	I4	NBRCH(J)	No. of beginning reach on branch "J"	repeat for J=1 through NBR on this one card
	5-8	I4	NLRCH(J)	No. of last reach on branch "J"	
	9-12	I4	NTRCH(J)	No. of main stem reach to which branch "J" is tributary (0 for J=1)	
3	1-80	15F5.3	RCLOC(I,J)	Location of downstream end of reach "I" and upstream end of uppermost reach	All reaches on one branch on one card: As many cards as there are branches
4	1-25	5F5.3	CPTLOC(IC)	Location of control points "IC"[a]	IC=1 to NCPTS
5	1-25	5F5.3	RESLOC(IR)	Location of reservoir "IR"[a]	IR=1 to NRES; Omits of NRES=0
6	1-25	5F5.3	EFLOC(IE)	Location of effluent discharge point "E"[a]	IE=1 to NEF
7	1-72	12A6	AMO(K)	Abbreviation of month no. "K"	K=1 to 12
8	1-80	16F5.1	ATEQ(I,J,1)	Equilibrium temperature constant	one pair for both ends of every reach. One set of cards for each branch. Omit if IY=0
9	1-80	16F5.3	ATEQ(I,J,2)	Equilibrium temperature coefficient	
10	1-72	12F6.3	AD(K,1)	Diurnal temperature index model parameter for each month	omit 10-13 if IZ=0
11	1-72	12F6.3	AD(K,2)		
12	1-72	12F6.3	AD(K,3)		
13	1-72	12F6.3	AD(K,4)		

Table E-3. Continued.

Card	Col	Format	Variable Name	Definition	Remarks
14	1-72	12F6.3	ADO(K,1)	Diurnal dissolved oxygen index model parameters for each month	omit 14-16 if IX=0
15	1-72	12F6.3	ADO(K,2)		
16	1-72	12F6.3	ADO(K,3)		
17	1-72	12F6.3	ADO(K,4)		
18	1-5	F5.1	RH(J)	Mean depth multiplier [b]	
	6-10	F5.1	PH(J)	Mean depth exponent	
	11-15	F5.1	RA(J)	Area of flow section multiplier	
	16-20	F5.1	PA(J)	Area of flow section exponent	
19	1-5	F5.0	AECS(I,J,1)	Surface inflow conductivity constant [b]	
	6-10	F5.3	AECS(I,J,2)	Surface inflow conductivity exponent	
	11-15	F5.0	AECGI(I,J)	Groundwater conductivity (μmhos/cm)	
	16-20	F5.0	AECIR(I,J,1)	Mean annual irrigation flow conductance	
	21-25	F5.0	AECIR(I,J,2)	First term irrig. return flow conductivity coefficient	omit 19 if IV=0
	26-35	F10.8	AECIR(I,J,3)	First term irrig. return flow conductivity phase shift	
	36-40	F5.0	AECIR(I,J,4)	Second term irrig. return flow conductivity coefficient	
	41-50	F10.8	AECIR(I,J,5)	Second term irrig. return flow conductivity phase shift	
20	1-5	F5.1	ATS(I,J,1)	Surface inflow temperature constant [b]	
	6-10	F5.3	ATS(I,J,2)	Surface inflow temperature coefficient	
	11-15	F5.1	ATGI(I,J,1)	Groundwater temperature constant	
	16-20	F5.1	ATGI(I,J,2)	Groundwater temperature coefficient	
	21-30	F10.8	ATGI(I,J,3)	Groundwater temperature phase shift	omit 20 if IY=0
	31-35	F5.1	ATIR(I,J,1)	Irrigation return flow temperature constant	
	36-40	F5.3	ATIR(I,J,2)	Irrigation return flow temperature coefficient	
	41-45	F5.1	RK(I,J)	Heat exchange coefficient multiplier	
	46-50	F5.1	PK(I,J)	Heat exchange coefficient exponent	
21	1-5	F5.1	ABODS(I,J,1)	Surface inflow mean annual ultimate BOD [b]	
	6-10	F5.1	ABODS(I,J,2)	Surface inflow ultimate BOD coefficient	
	11-15	F5.3	ABODS(I,J,3)	Surface inflow ultimate BOD phase shift	
	16-20	F5.2	R1S(I,J)	Surface inflow deoxygenation rate constant (base 10)	
	21-25	F5.1	BODIR(I,J)	Irrigation return flow ultimate BOD	
	26-30	F5.2	R1IR(I,J)	Irrigation return flow deoxygenation rate constant (base 10)	
	31-35	F5.1	BODGI(I,J)	Groundwater ultimate BOD	omit 21 if IW=0
	36-40	F5.2	R1GI(I,J)	Groundwater deoxygenation rate constant (base 10)	
	41-45	F5.2	R1B(I,J)	Deoxygenation rate decrement (base 10)	
	46-50	F5.2	RP(I,J)	Scour rate constant	
	51-55	F5.2	R3(I,J)	Deposition rate constant for organics	
	56-60	F5.2	RR(I,J)	Difference between lab and river deoxygenation rate constants (base 10)	

Table E-3. Continued.

Card	Col	Format	Variable Name	Definition	Remarks
	61-65	F5.4	R4(I,J)	Anaerobic decay rate constant for benthal deposits	
	66-70	F5.1	BBOD(I,J)	Areal BOD of stream bottom (mg/sq.m.)	
22	1-5	F5.1	ADOS(I,J,1)	Surface inflow mean annual D.O. (mg/l)[b]	
	6-10	F5.3	ADOS(I,J,2)	Surface inflow first term D.O. coefficient	
	11-15	F5.3	ADOS(I,J,3)	Surface inflow first term D.O. phase shift	
	16-20	F5.3	ADOS(I,J,4)	Surface inflow second term D.O. coefficient	
	21-25	F5.3	ADOS(I,J,5)	Surface inflow second term D.O. phase shift	
	26-30	F5.1	ADOIR(I,J,1)	Irrigation return flow mean annual D.O.	
	31-35	F5.3	ADOIR(I,J,2)	Irrigation return flow first term D.O. coefficient	
	36-40	F5.3	ADOIR(I,J,3)	Irrigation return flow first term D.O. phase shift	
	41-45	F5.3	ADOIR(I,J,4)	Irrigation return flow second term D.O. coefficient	omit 22 if IW=0
	46-50	F5.3	ADOIR(I,J,5)	Irrigation return flow second term D.O. phase shift	
	51-55	F5.1	ADOGI(I,J,1)	Groundwater mean annual D.O. (mg/l)	
	56-60	F5.3	ADOGI(I,J,2)	Groundwater D.O. coefficient	
	61-65	F5.3	ADOGI(I,J,3)	Groundwater D.O. phase shift	
23	1-60	12F5.1	PCON(I,J,K)	Productivity constant for each month[b]	omit 23 if IW=0
24	1-5	F5.0	ECST(IR,1)	Conductivity of water in storage at beginning of simulation	
	6-11	F6.0	VSTI(IR,1)	Volume of water in storage at beginning of simulation (acre-feet)	
	12-17	F6.0	VMAX(IR)	Storage capacity of reservoir (acre-feet)	
	18-22	F5.1	AT(IR,1,1)	Mean annual temperature of reservoir discharge (°C)	
	23-27	F5.1	AT(IR,1,2)	First term coefficient in reservoir discharge temp. model	
	28-32	F5.1	AT(IR,1,3)	Second term coefficient in reservoir discharge temp. model	
	33-37	F5.1	AT(IR,1,4)	Third term coefficient in reservoir discharge temp. model	IR=1 to NRES
	38-42	F5.1	AT(IR,1,5)	Fourth term coefficient in reservoir discharge temp. model	omit if NRES=0
	43-47	F5.3	AT(IR,2,1)	First term phase shift in reservoir discharge temp. model	
	48-52	F5.3	AT(IR,2,2)	Second term phase shift in reservoir discharge temp. model	
	53-57	F5.3	AT(IR,2,3)	Third term phase shift in reservoir discharge temp. model	
	58-62	F5.3	AT(IR,2,4)	Fourth term phase shift in reservoir discharge temp. model	
25	1-5	F5.1	ABDR(IR,1)	Mean annual ultimate BOD of reservoir discharge (mg/l)	
	6-10	F5.1	ABDR(IR,2)	Coefficient in reservoir discharge BOD model	
	11-15	F5.3	ABDR(IR,3)	Phase shift in reservoir discharge BOD model	

Table E-3. Continued.

Card	Col	Format	Variable Name	Definition	Remarks
	16-20	F5.1	ADOR(IR,1)	Mean annual D.O. of reservoir discharge (mg/l)	
	21-25	F5.1	ADOR(IR,2)	Coefficient in reservoir discharge D.O. model	
	26-30	F5.3	ADOR(IR,3)	Phase shift in reservoir discharge D.O. model	
26	1-60	12F5.1	TAIR(K)	Average of mean daily temperatures for each month	omit if IY=0
27	1-5	F5.1	QEF(IE,JF)	Mean monthly discharge rate at effluent point "IEF" (EFS)	
	6-10	F5.1	ECEF(IE,JE)	Mean monthly conductance at effluent point "IEF"	
	11-15	F5.1	TEF(IE,JE)	Mean monthly effluent temp. at effluent point "IEF" ($^{\circ}$C)	
	16-20	F5.1	DOEF(IE,JE)	Mean monthly effluent D.O. at effluent point "IEF" (mg/l)	
	21-25	F5.1	BODEF(IE,JE)	Mean monthly effluent BOD at effluent point "IEF" (mg/l)	
	26-30	F5.2	R1EF(IE,JE)	Mean monthly deoxygenation rate constant (day $^{-1}$, base 10)	
28	1-72	24F3.2	QEFI(IEF,MT)	Diurnal discharge index at effluent point "IEF"	IEF=1 to NEF
29	1-72	24F3.2	TEFI(IEF,MT)	Diurnal temperature index at effluent point "IEF"	omit 27-31 if NEF=0 omit 29 if IZ=0
30	1-72	24F3.2	DOEFI(IEF,MT)	Diurnal D.O. index at effluent point "IEF"	omit 30 if IX=0
31	1-72	24F3.2	BODEFI(IEF,MT)	Diurnal BOD index at effluent point "IEF"	omit if IX=0
32	1-5	F5.1	QA(I,J)	Diffuse natural surface inflow (cfs)	
	6-10	F5.1	QIR(I,J)	Irrigation return flows (cfs)	
	11-15	F5.1	QGI(I,J)	Groundwater inflow (cfs)	repeat for all reaches [c]
	16-20	F5.1	QD(I,J)	Diversions (cfs)	
	21-25	F5.1	QEV	Reservoir evaporation (cfs)	cols 21-37
	26-31	F6.0	VST(IR)	Volume of stored water at end of month (acre-feet)	omit cols 21-37 if reach is not a reservoir
	32-37	F6.1	RD(IR)	Depth from reservoir surface to outlet works (feet)	

---

[a] Location designations are coded so that X.xxx, X is the branch on which the point is located and xx.x is the distance from the mouth of the branch in miles.

[b] Card 18 for branch no. 1 (main stem), cards 19 through 23 for every reach on that branch, beginning with the reach nearest the downstream end of the system; card 18 for branch no. 2 cards 19 through 23 for every reach on that branch, starting with the nearest the mouth, etc.

[c] Starting with month no. 1 (Oct.) cards 27 through 31 for each effluent discharge point, followed by card no. 32 for each reach in the system beginning with the highest reach on the main stem, proceeding downstream until a reach with tributary branch is contacted. Next enter card 32 for all reaches on the tributary branch, followed by the card for the reach to which the branch is a tributary, etc. until finally card 32 for the lowest reach on the main stem is the last card for the month.

APPENDIX F

COMPARISON OF OBSERVED AND SIMULATED 1968 WATER QUALITY PROFILES

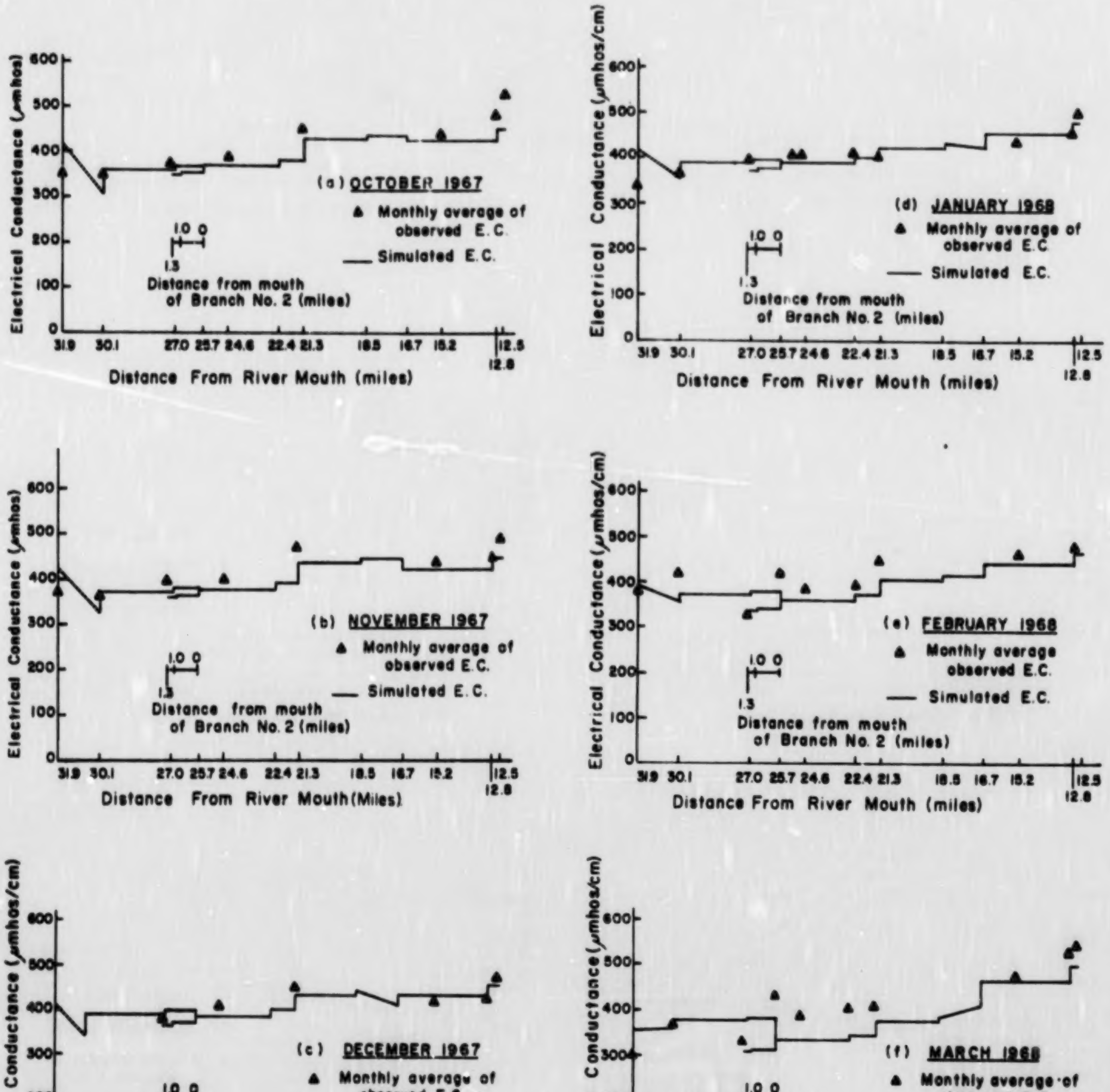


Figure F-1. Comparison of observed and simulated 1968 electrical conductance profiles.

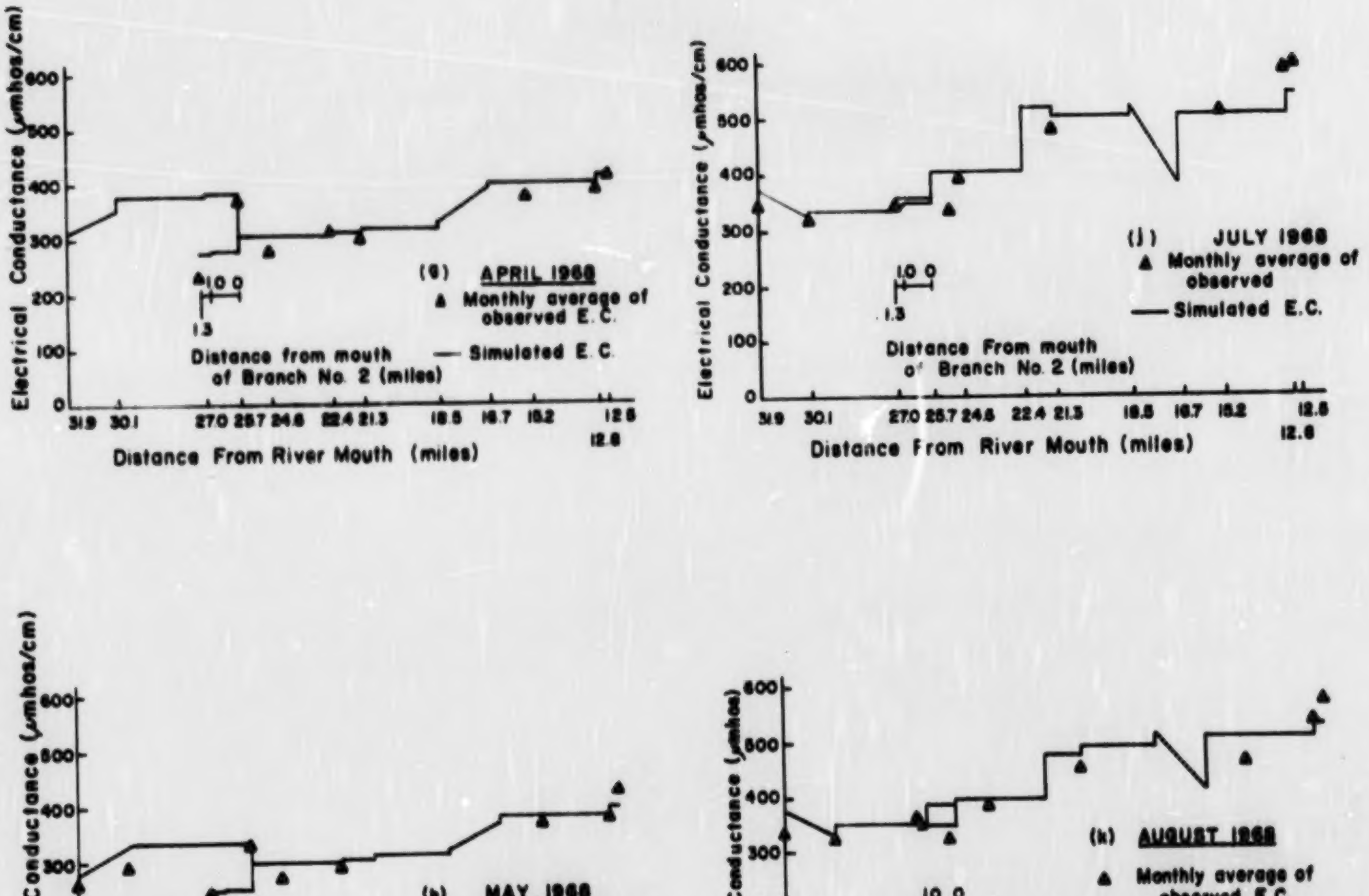


Figure F-1. Continued.

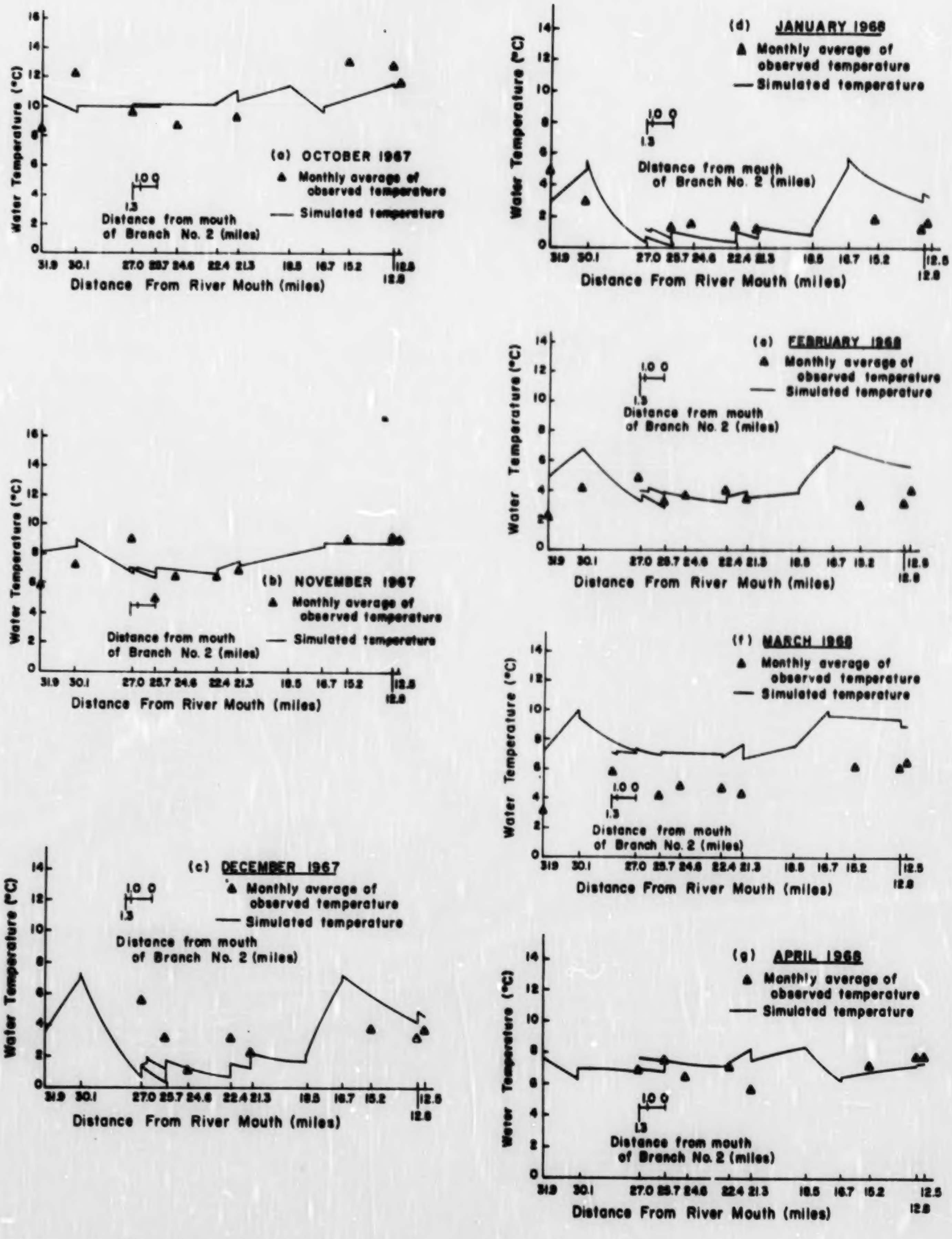


Figure F-2. Comparison of observed and simulated 1968 stream temperature profiles.

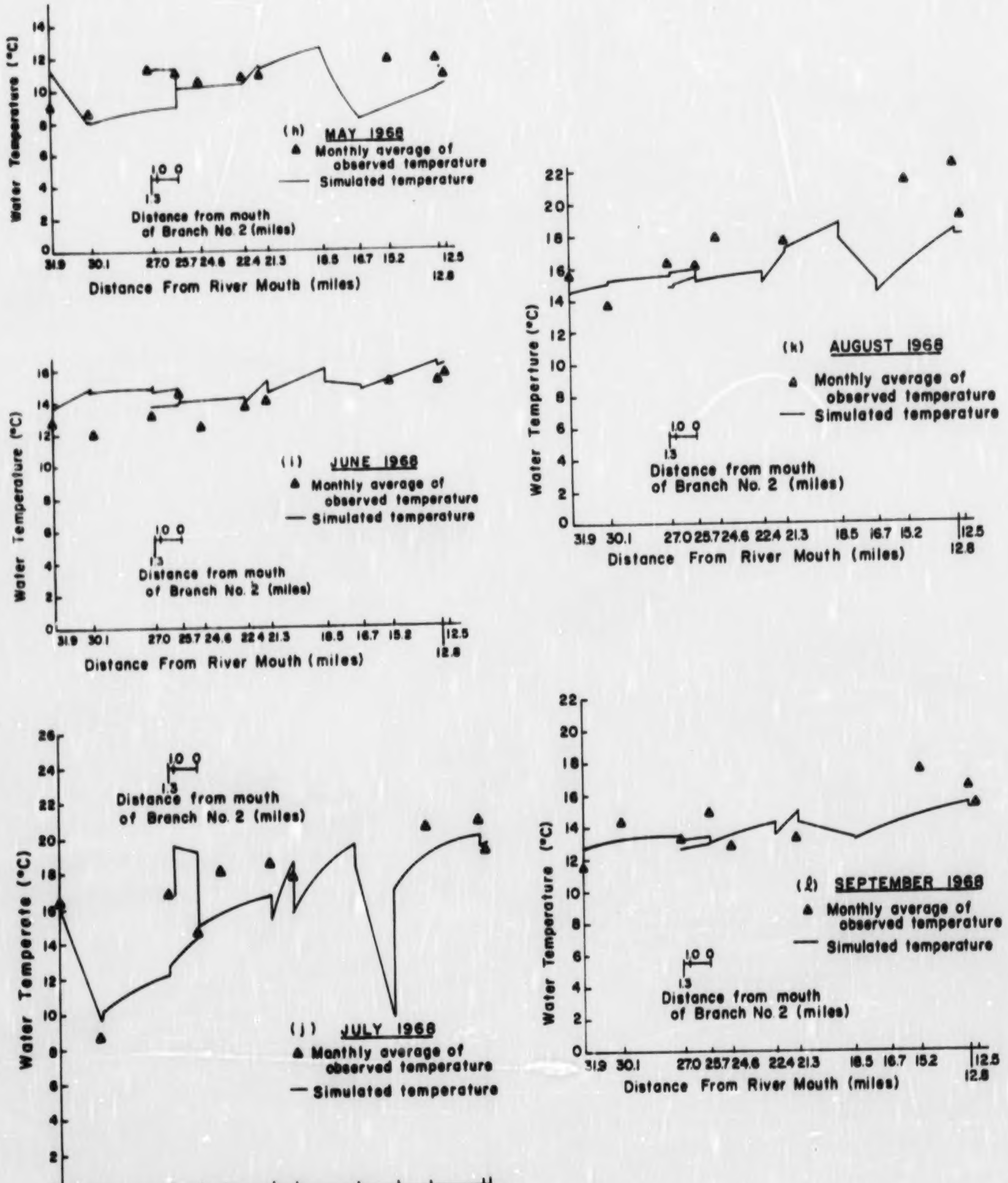


Figure F-2. Continued.

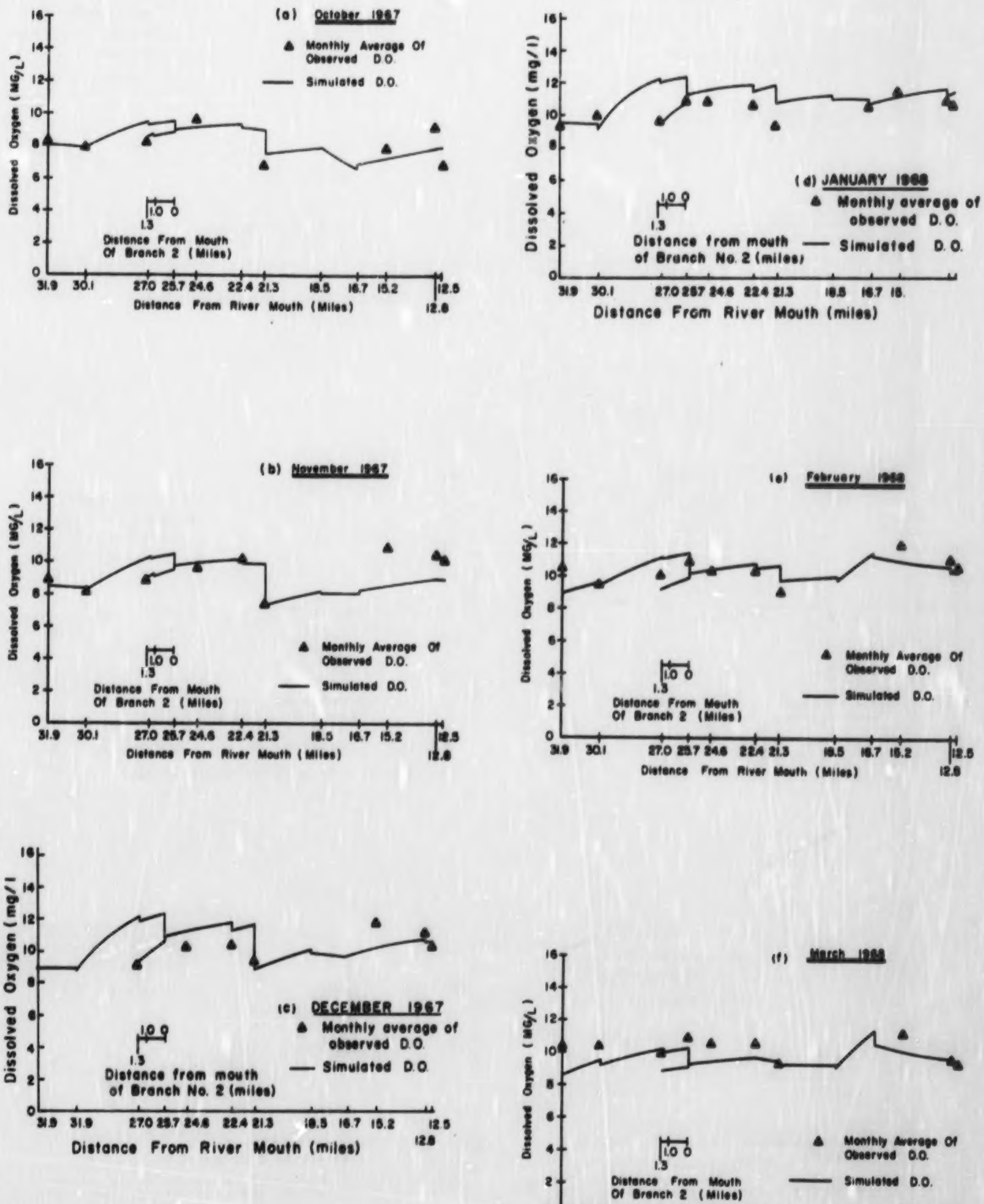


Figure F-3. Comparison of observed and simulated 1968 dissolved oxygen profile.

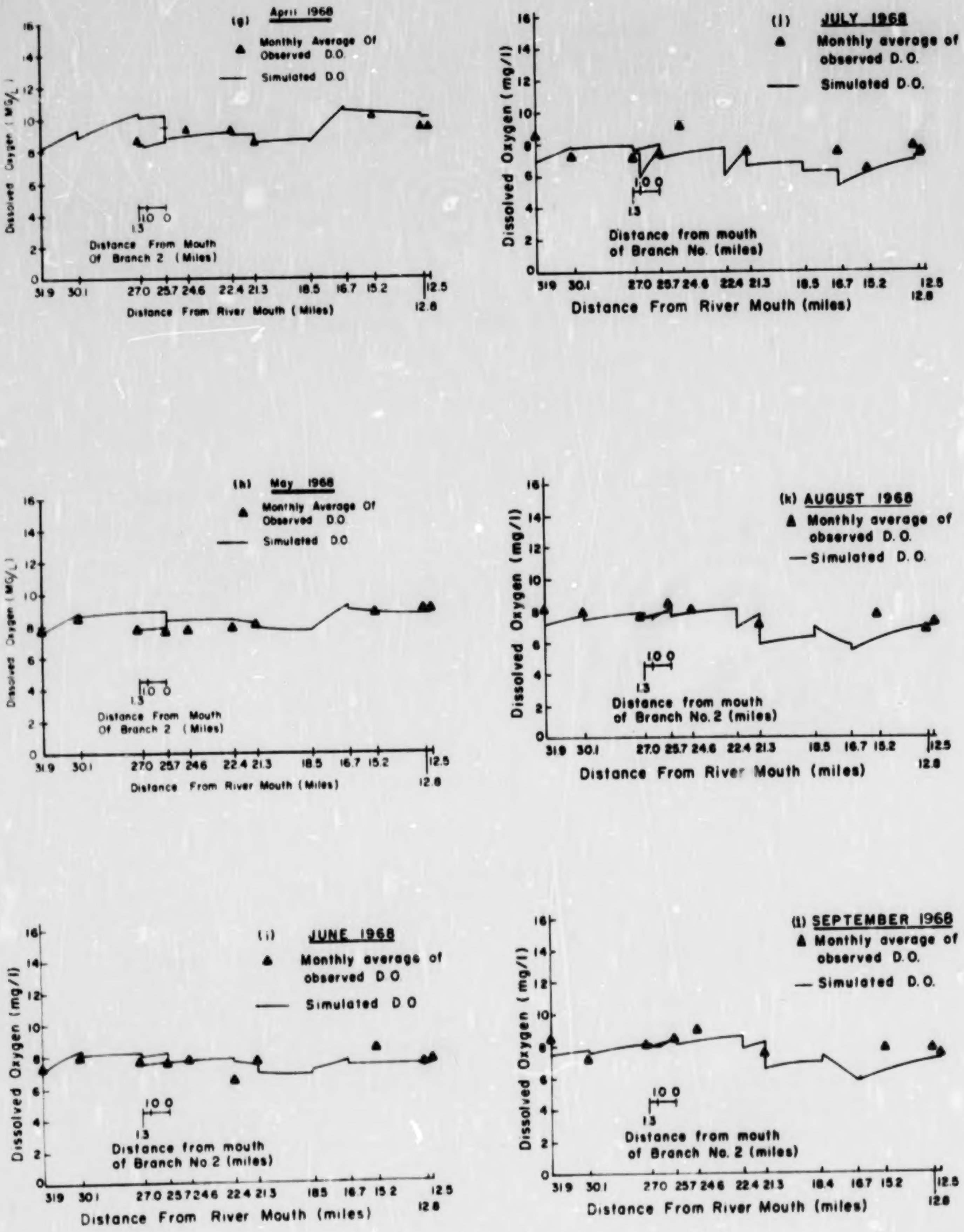


Figure F-3. Continued.

APPENDIX G

HYDROLOGY MODEL COMPUTER PROGRAMS–(1) HYDRO, (2) BUDGET–INSTRUCTIONS FOR USE

The computer programs for the hydrologic model of a river basin were coded in FORTRAN V for use on the UNIVAC 1108 digital computer. Both programs require the same deck set-up and yield the same results except that HYDRO is designed for using only data for one year at a time and can iterate over selected model parameters whereas BUDGET can take input data for up to 30 years and output a mean and standard deviation budget for the data input. The program BUDGET is designed for use primarily after a particular model has been validated and stochastic information about the system is desired.

A schematic diagram of the model is given in Figure G-1 with the flow chart shown in Figure G-2. Table G-1 gives the notation used in the programming of the model.

Both programs are designed to run in a batch mode, that is, after completing one simulation run control is passed to the start of the program to start another run if data are supplied for it. The data are separated into three groups of cards. The first group, consisting of 20 cards, merely contains labels for the tabular budget which will be output and are read only once during a run. The second group consisting of 8 cards, is the control and parameter initialization cards for the particular river basin being simulated. The last group contains the actual input data for that run.

Detailed instruction for preparing the three groups of data cards needed as input to the program are given in Tables G-2, G-3, and G-4 respectively. Table G-5 gives the valid iteration codes that may be specified when using HYDRO.

A diagram of the correct deck set-up for a run is shown in Figure G-3. A listing of program HYDRO with sample problem input data is shown in Figure G-4. A listing of program BUDGET with a listing of the correct deck set-up for simulating the two study areas is shown in Figure G-5. The computer output for the run set up in Figure G-5 is included in Figure G-6.

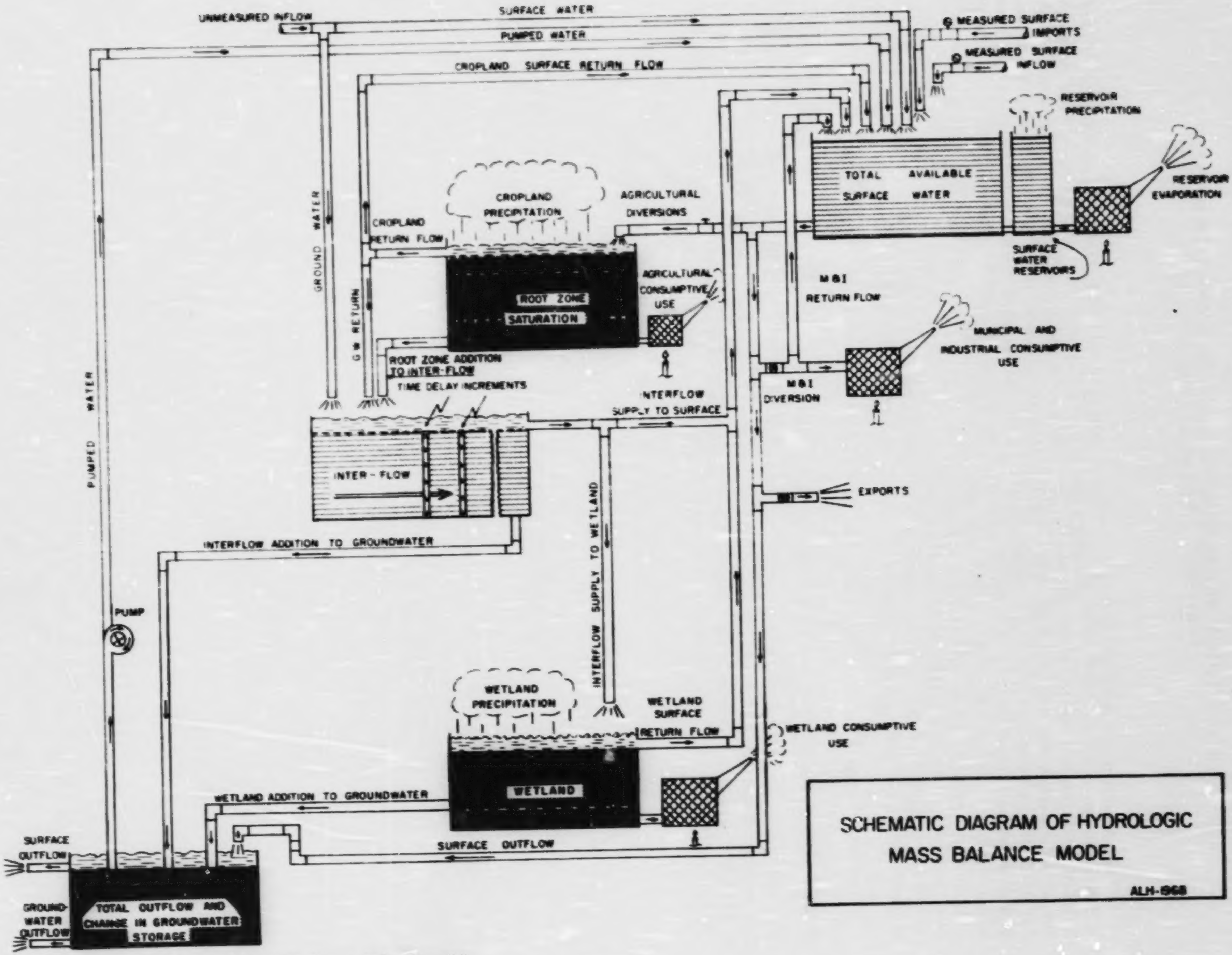

UNMEASURED INFLOW
SURFACE WATER
PUMPED WATER
CROPLAND SURFACE RETURN FLOW
MEASURED SURFACE IMPORTS
MEASURED SURFACE INFLOW
RESERVOIR PRECIPITATION
TOTAL AVAILABLE SURFACE WATER
RESERVOIR EVAPORATION
SURFACE WATER RESERVOIRS
CROPLAND PRECIPITATION
AGRICULTURAL DIVERSIONS
CROPLAND RETURN FLOW
GROUND WATER
G W RETURN
ROOT ZONE
SATURATION
AGRICULTURAL CONSUMPTIVE USE
M&I RETURN FLOW
MUNICIPAL AND INDUSTRIAL CONSUMPTIVE USE
M&I DIVERSION
ROOT ZONE ADDITION TO INTER-FLOW
TIME DELAY INCREMENTS
INTERFLOW SUPPLY TO SURFACE
INTER - FLOW
EXPORTS
PUMPED WATER
INTERFLOW ADDITION TO GROUNDWATER
INTERFLOW SUPPLY TO WETLAND
PUMP
WETLAND PRECIPITATION
WETLAND SURFACE RETURN FLOW
WETLAND CONSUMPTIVE USE
WETLAND
WETLAND ADDITION TO GROUNDWATER
SURFACE OUTFLOW
SURFACE OUTFLOW
TOTAL OUTFLOW AND CHANGE IN GROUNDWATER STORAGE
GROUND-WATER OUTFLOW
SCHEMATIC DIAGRAM OF HYDROLOGIC MASS BALANCE MODEL
ALH-1968

Figure G-1. Schematic diagram of hydrologic mass balance model.

HYDROLOGIC MASS BALANCE MODEL

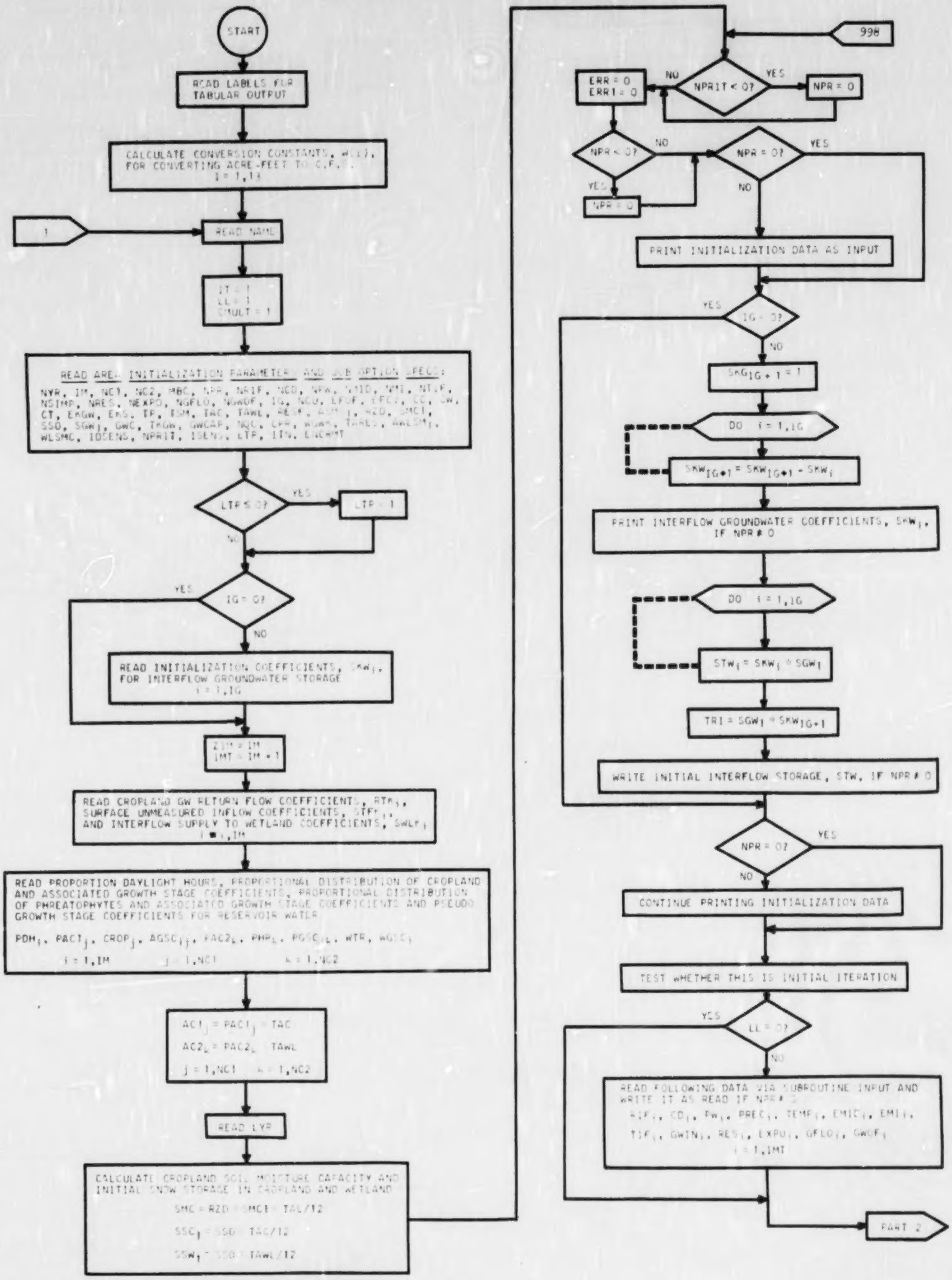

START
READ LABELS FOR TABULAR OUTPUT
CALCULATE CONVERSION CONSTANTS, W(I), FOR CONVERTING ACRE-FEET TO C.F.S.
I = 1,13
1
READ NAME
IT = 1
LL = 1
CMULT = 1
READ AREA INITIALIZATION PARAMETERS AND JOB OPTION SPECS:
NYR, IM, NC1, NC2, MBC, NPR, NRIF, NCD, NPW, NMID, NMI, NTIF,
NSIMP, NRES, NEXPO, NGFLO, NGWOF, IG, NCU, EFOF, EFCU, CC, CW,
CT, EKGW, EKS, TP, TSM, TAC, TAWL, RESF, AGM, RZD, SMC1,
SSO, SGW1, GWC, TKGW, GWCAP, NQC, CPR, WGWR, TARES, AWLSM1,
WLSMC, IDSENS, NPRIT, ISENS, LTP, ITN, ENCHMT
LTP ≤ 0?
YES
LTP = 1
NO
IG = 0?
YES
NO
READ INITIALIZATION COEFFICIENTS, SKW1, FOR INTERFLOW GROUNDWATER STORAGE
i = 1,IG
ZIM = IM
IMT = IM + 1
READ CROPLAND GW RETURN FLOW COEFFICIENTS, RTKi, SURFACE UNMEASURED INFLOW COEFFICIENTS, STFi, AND INTERFLOW SUPPLY TO WETLAND COEFFICIENTS, SWLFi
i = 1,IM
READ PROPORTION DAYLIGHT HOURS, PROPORTIONAL DISTRIBUTION OF CROPLAND AND ASSOCIATED GROWTH STAGE COEFFICIENTS, PROPORTIONAL DISTRIBUTION OF PHREATOPHYTES AND ASSOCIATED GROWTH STAGE COEFFICIENTS AND PSEUDO GROWTH STAGE COEFFICIENTS FOR RESERVOIR WATER
PDHi, PAC1j, CROPj, AGSCij, PAC2k, PHRk, PGSCik, WTR, WGSCi
i = 1,IM j = 1,NC1 k = 1,NC2
AC1j = PAC1j * TAC
AC2k = PAC2k * TAWL
j = 1,NC1 k = 1,NC2
READ LYR
CALCULATE CROPLAND SOIL MOISTURE CAPACITY AND INITIAL SNOW STORAGE IN CROPLAND AND WETLAND
SMC = RZD * SMC1 * TAC/12
SSC1 = SSO * TAC/12
SSW1 = SSO * TAWL/12
998
NO
NPRIT < 0?
YES
ERR = 0
ERR1 = 0
NPR = 0
NPR < 0?
NO
NPR = 0?
YES
YES
NPR = 0
NO
PRINT INITIALIZATION DATA AS INPUT
YES
IG = 0?
NO
SKGIG + 1 = 1
DO i = 1,IG
SKWIG+1 = SKWIG+1 - SKWi
PRINT INTERFLOW GROUNDWATER COEFFICIENTS, SKWi, IF NPR ≠ 0
DO i = 1,IG
STWi = SKWi * SGW1
TR1 = SGW1 * SKWIG+1
WRITE INITIAL INTERFLOW STORAGE, STW, IF NPR ≠ 0
NPR = 0?
YES
NO
CONTINUE PRINTING INITIALIZATION DATA
TEST WHETHER THIS IS INITIAL ITERATION
YES
LL = 0?
NO
READ FOLLOWING DATA VIA SUBROUTINE INPUT AND WRITE IT AS READ IF NPR ≠ 0
RIFi, CDi, PWi, PRECi, TEMPi, EMIDi, EMIi,
TIFi, GWINi, RESi, EXPOi, GFLOi, GWOFi
i = 1,IMT
PART 2

Figure G-2. HYDRO-BUDGET computer program flow chart.

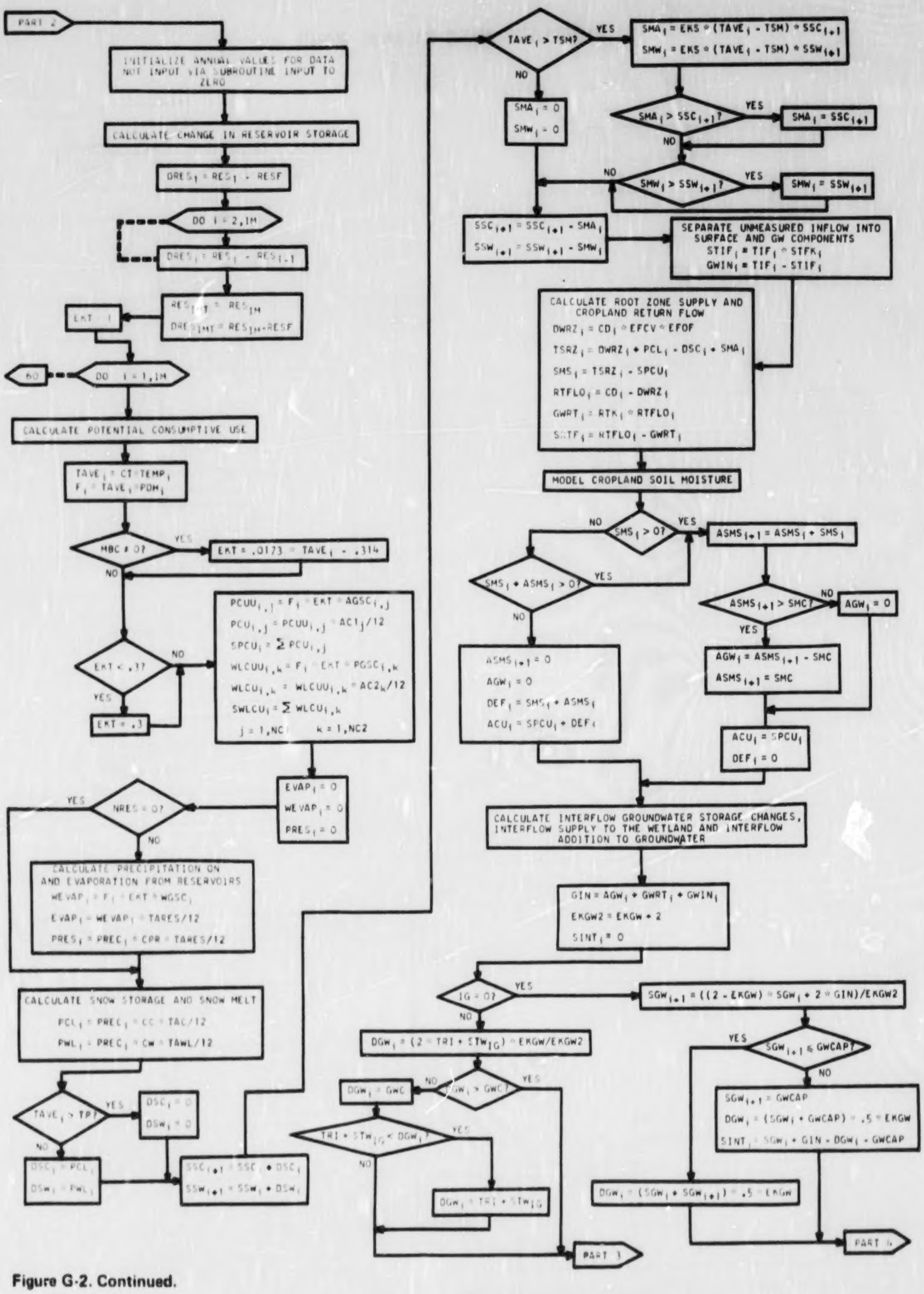
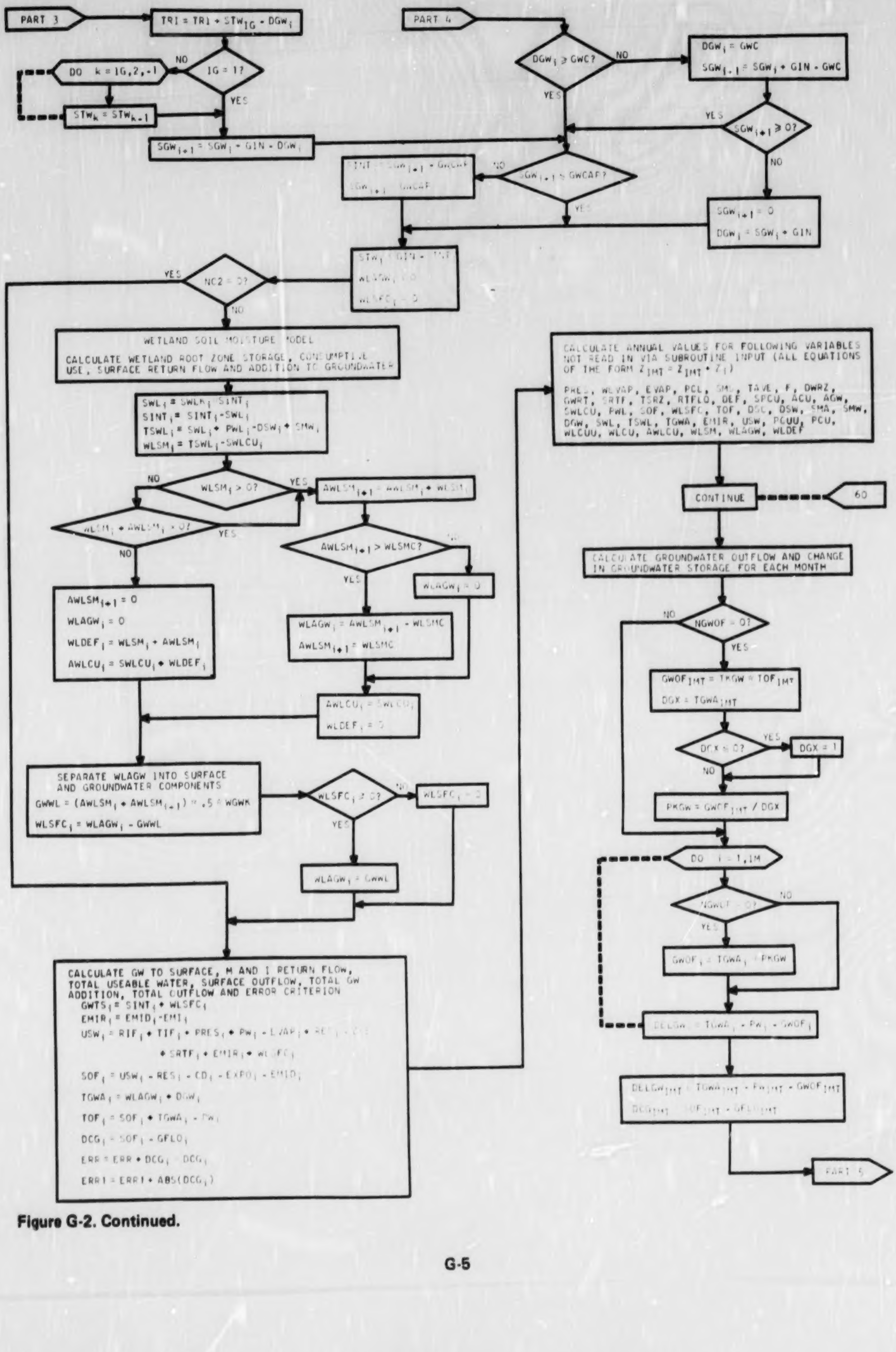

PART 2
INITIALIZE ANNUAL VALUES FOR DATA NOT INPUT VIA SUBROUTINE INPUT TO ZERO
CALCULATE CHANGE IN RESERVOIR STORAGE
DRES1 = RES1 - RESF
DO i = 2,IM
DRESi = RESi - RESi-1
RESIMT = RESIM
DRESIMT = RESIM-RESF
EKT = 1
60
DO i = 1,IM
CALCULATE POTENTIAL CONSUMPTIVE USE
TAVEi = CT*TEMPi
Fi = TAVEi*PDHi
MBC ≠ 0?
YES
EKT = .0173 * TAVEi - .314
NO
EKT < .3?
NO
YES
EKT = .3
PCUUi,j = Fi * EKT * AGSCi,j
PCUi,j = PCUUi,j * AC1j/12
SPCUi = Σ PCUi,j
WLCUUi,k = Fi * EKT * PGSCi,k
WLCUi,k = WLCUUi,k * AC2k/12
SWLCUi = Σ WLCUi,k
j = 1,NC1   k = 1,NC2
EVAPi = 0
WEVAPi = 0
PRESi = 0
NRES = 0?
YES
NO
CALCULATE PRECIPITATION ON AND EVAPORATION FROM RESERVOIRS
WEVAPi = Fi * EKT * WGSCi
EVAPi = WEVAPi * TARES/12
PRESi = PRECi * CPR * TARES/12
CALCULATE SNOW STORAGE AND SNOW MELT
PCLi = PRECi * CC * TAC/12
PWLi = PRECi * CW * TAWL/12
TAVEi > TP?
YES
NO
DSCi = 0
DSWi = 0
DSCi = PCLi
DSWi = PWLi
SSCi+1 = SSCi + DSCi
SSWi+1 = SSWi + DSWi
TAVEi > TSM?
YES
NO
SMAi = EKS * (TAVEi - TSM) * SSCi+1
SMWi = EKS * (TAVEi - TSM) * SSWi+1
SMAi = 0
SMWi = 0
SMAi > SSCi+1?
YES
NO
SMAi = SSCi+1
SMWi > SSWi+1?
YES
NO
SMWi = SSWi+1
SSCi+1 = SSCi+1 - SMAi
SSWi+1 = SSWi+1 - SMWi
SEPARATE UNMEASURED INFLOW INTO SURFACE AND GW COMPONENTS
STIFi = TIFi * STFKi
GWINi = TIFi - STIFi
CALCULATE ROOT ZONE SUPPLY AND CROPLAND RETURN FLOW
DWRZi = CDi * EFCV * EFOF
TSRZi = DWRZi + PCLi - DSCi + SMAi
SMSi = TSRZi - SPCUi
RTFLOi = CDi - DWRZi
GWRTi = RTKi * RTFLOi
SWRTFi = RTFLOi - GWRTi
MODEL CROPLAND SOIL MOISTURE
SMSi > 0?
NO
YES
ASMSi+1 = ASMSi + SMSi
SMSi + ASMSi > 0?
YES
NO
ASMSi+1 > SMC?
NO
YES
AGWi = 0
ASMSi+1 = 0
AGWi = 0
DEFi = SMSi + ASMSi
ACUi = SPCUi + DEFi
AGWi = ASMSi+1 - SMC
ASMSi+1 = SMC
ACUi = SPCUi
DEFi = 0
CALCULATE INTERFLOW GROUNDWATER STORAGE CHANGES, INTERFLOW SUPPLY TO THE WETLAND AND INTERFLOW ADDITION TO GROUNDWATER
GIN = AGWi + GWRTi + GWINi
EKGW2 = EKGW + 2
SINTi = 0
IG = 0?
YES
NO
SGWi+1 = ((2 - EKGW) * SGWi + 2 * GIN)/EKGW2
DGWi = (2 * TRI + STWIG) * EKGW/EKGW2
DGWi > GWC?
NO
YES
DGWi = GWC
TRI + STWIG < DGWi?
YES
NO
DGWi = TRI + STWIG
SGWi+1 ≤ GWCAP?
YES
NO
SGWi+1 = GWCAP
DGWi = (SGWi + GWCAP) * .5 * EKGW
SINTi = SGWi + GIN - DGWi - GWCAP
DGWi = (SGWi + SGWi+1) * .5 * EKGW
PART 3
PART 4

Figure G-2. Continued.



PART 3
$TRI = TRI + STW_{IG} - DGW_i$
$IG = 1?$
NO
YES
DO k = IG,2,-1
$STW_k = STW_{k-1}$
$SGW_{i+1} = SGW_i + GIN - DGW_i$
PART 4
$DGW_i \geq GWC?$
NO
YES
$DGW_i = GWC$
$SGW_{i+1} = SGW_i + GIN - GWC$
$SGW_{i+1} \geq 0?$
YES
NO
$SGW_{i+1} = 0$
$DGW_i = SGW_i + GIN$
$SGW_{i+1} \leq GWCAP?$
NO
YES
$SINT_i = SGW_{i+1} - GWCAP$
$SGW_{i+1} = GWCAP$
$STW_i = GIN - SINT_i$
$WLAGW_i = 0$
$WLSFC_i = 0$
$NC2 = 0?$
YES
NO
WETLAND SOIL MOISTURE MODEL
CALCULATE WETLAND ROOT ZONE STORAGE, CONSUMPTIVE USE, SURFACE RETURN FLOW AND ADDITION TO GROUNDWATER
$SWL_i = SWLR_i + SINT_i$
$SINT_i = SINT_i - SWL_i$
$TSWL_i = SWL_i + PWL_i - DSW_i + SMW_i$
$WLSM_i = TSWL_i - SWLCU_i$
$WLSM_i > 0?$
NO
YES
$WLSM_i + AWLSM_i > 0?$
YES
NO
$AWLSM_{i+1} = AWLSM_i + WLSM_i$
$AWLSM_{i+1} > WLSMC?$
NO
YES
$WLAGW_i = 0$
$WLAGW_i = AWLSM_{i+1} - WLSMC$
$AWLSM_{i+1} = WLSMC$
$AWLSM_{i+1} = 0$
$WLAGW_i = 0$
$WLDEF_i = WLSM_i + AWLSM_i$
$AWLCU_i = SWLCU_i + WLDEF_i$
$AWLCU_i = SWLCU_i$
$WLDEF_i = 0$
SEPARATE WLAGW INTO SURFACE AND GROUNDWATER COMPONENTS
$GWWL = (AWLSM_i + AWLSM_{i+1}) * .5 * WGWK$
$WLSFC_i = WLAGW_i - GWWL$
$WLSFC_i \geq 0?$
NO
YES
$WLSFC_i = 0$
$WLAGW_i = GWWL$
CALCULATE GW TO SURFACE, M AND I RETURN FLOW, TOTAL USEABLE WATER, SURFACE OUTFLOW, TOTAL GW ADDITION, TOTAL OUTFLOW AND ERROR CRITERION
$GWTS_i = SINT_i + WLSFC_i$
$EMIR_i = EMID_i - EMI_i$
$USW_i = RIF_i + TIF_i + PRES_i + PW_i - EVAP_i + RES_{i-1} - CS_i$
$+ SRTF_i + EMIR_i + WLSFC_i$
$SOF_i = USW_i - RES_i - CD_i - EXPO_i - EMID_i$
$TGWA_i = WLAGW_i + DGW_i$
$TOF_i = SOF_i + TGWA_i - PW_i$
$DCG_i = SOF_i - GFLO_i$
$ERR = ERR + DCG_i - DCG_i$
$ERR1 = ERR1 + ABS(DCG_i)$
CALCULATE ANNUAL VALUES FOR FOLLOWING VARIABLES NOT READ IN VIA SUBROUTINE INPUT (ALL EQUATIONS OF THE FORM $Z_{IMT} = Z_{IMT} + Z_i$)
PRES, WLVAP, EVAP, PCL, SMD, TAVE, F, DWRZ, GWRT, SRTF, TSRZ, RTFLO, DEF, SPCU, ACU, AGW, SWLCU, PWL, SOF, WLSFC, TOF, DSC, DSW, SMA, SMW, DGW, SWL, TSWL, TGWA, EMIR, USW, PCUU, PCU, WLCUU, WLCU, AWLCU, WLSM, WLAGW, WLDEF
CONTINUE
60
CALCULATE GROUNDWATER OUTFLOW AND CHANGE IN GROUNDWATER STORAGE FOR EACH MONTH
$NGWOF = 0?$
NO
YES
$GWOF_{IMT} = TKGW * TOF_{IMT}$
$DGX = TGWA_{IMT}$
$DGX \leq 0?$
YES
NO
$DGX = 1$
$PKGW = GWOF_{IMT} / DGX$
DO i = 1,IM
$NGWOF = 0?$
NO
YES
$GWOF_i = TGWA_i * PKGW$
$DELGW_i = TGWA_i - PW_i - GWOF_i$
$DELGW_{IMT} = TGWA_{IMT} - PW_{IMT} - GWOF_{IMT}$
$DCG_{IMT} = SOF_{IMT} - GFLO_{IMT}$
PART 5

Figure G-2. Continued.

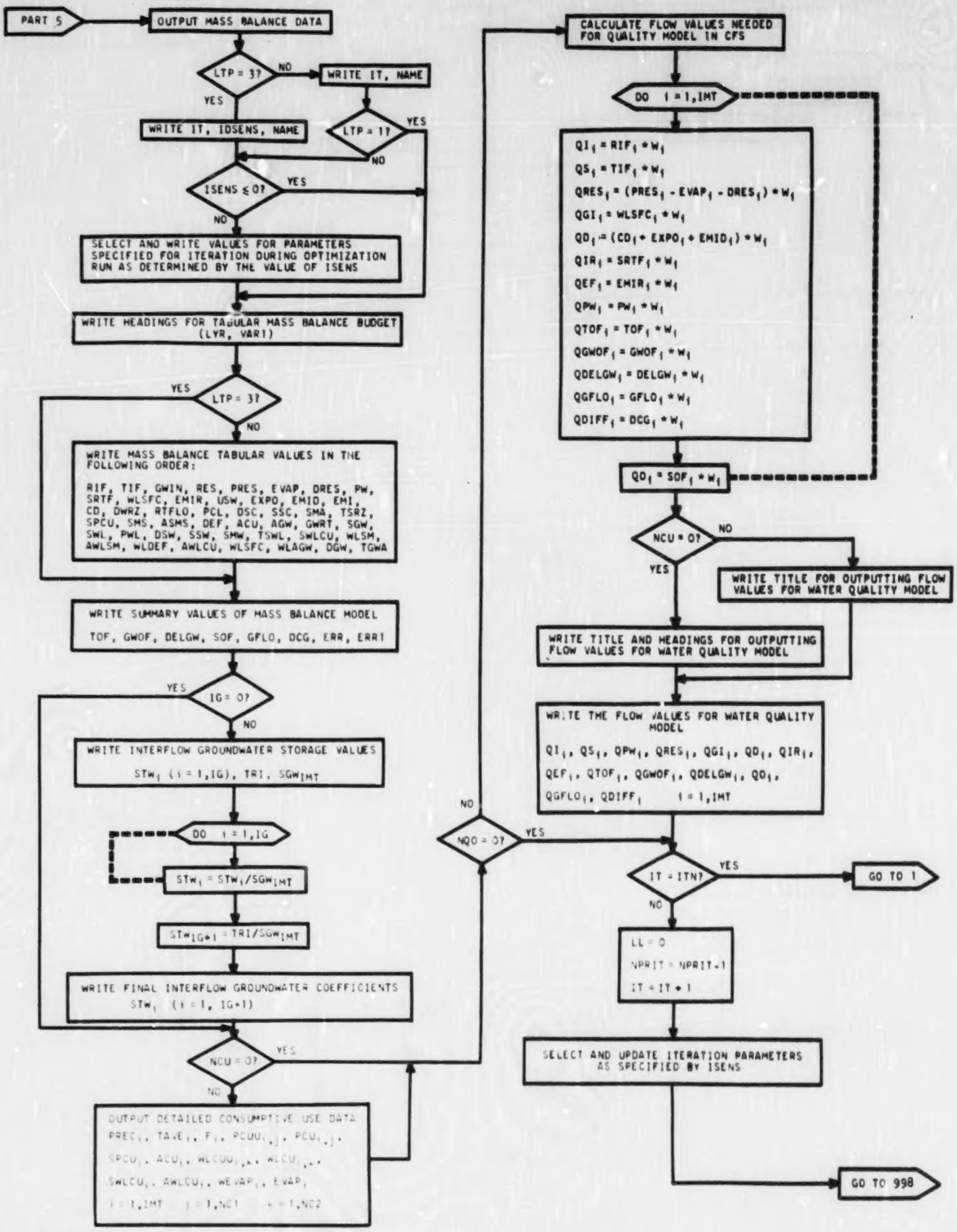

PART 5
OUTPUT MASS BALANCE DATA
LTP = 3?
NO
YES
WRITE IT, NAME
LTP = 1?
YES
NO
WRITE IT, IDSENS, NAME
ISENS ≤ 0?
YES
NO
SELECT AND WRITE VALUES FOR PARAMETERS SPECIFIED FOR ITERATION DURING OPTIMIZATION RUN AS DETERMINED BY THE VALUE OF ISENS
WRITE HEADINGS FOR TABULAR MASS BALANCE BUDGET (LYR, VAR1)
LTP = 3?
YES
NO
WRITE MASS BALANCE TABULAR VALUES IN THE FOLLOWING ORDER:
RIF, TIF, GWIN, RES, PRES, EVAP, DRES, PW, SRTF, WLSFC, EMIR, USW, EXPO, EMID, EMI, CD, DWRZ, RTFLO, PCL, DSC, SSC, SMA, TSRZ, SPCU, SMS, ASMS, DEF, ACU, AGW, GWRT, SGW, SWL, PWL, DSW, SSW, SMW, TSWL, SWLCU, WLSM, AWLSM, WLDEF, AWLCU, WLSFC, WLAGW, DGW, TGWA
WRITE SUMMARY VALUES OF MASS BALANCE MODEL
TOF, GWOF, DELGW, SOF, GFLO, DCG, ERR, ERR1
IG = 0?
YES
NO
WRITE INTERFLOW GROUNDWATER STORAGE VALUES
STW_i $(i = 1, IG)$, TRI, SGW_{IMT}
DO i = 1,IG
$STW_i = STW_i/SGW_{IMT}$
$STW_{IG+1} = TRI/SGW_{IMT}$
WRITE FINAL INTERFLOW GROUNDWATER COEFFICIENTS
STW_i $(i = 1, IG+1)$
NCU = 0?
YES
NO
OUTPUT DETAILED CONSUMPTIVE USE DATA
$PREC_i$, $TAVE_i$, F_i, $PCUU_{i,j}$, $PCU_{i,j}$,
$SPCU_i$, ACU_i, $WLCUU_{i,k}$, $WLCU_{i,k}$,
$SWLCU_i$, $AWLCU_i$, $WEVAP_i$, $EVAP_i$
i = 1,IMT j = 1,NC1 k = 1,NC2
NQO = 0?
NO
YES
CALCULATE FLOW VALUES NEEDED FOR QUALITY MODEL IN CFS
DO i = 1,IMT
$QI_i = RIF_i * W_i$
$QS_i = TIF_i * W_i$
$QRES_i = (PRES_i - EVAP_i - DRES_i) * W_i$
$QGI_i = WLSFC_i * W_i$
$QD_i = (CD_i + EXPO_i + EMID_i) * W_i$
$QIR_i = SRTF_i * W_i$
$QEF_i = EMIR_i * W_i$
$QPW_i = PW_i * W_i$
$QTOF_i = TOF_i * W_i$
$QGWOF_i = GWOF_i * W_i$
$QDELGW_i = DELGW_i * W_i$
$QGFLO_i = GFLO_i * W_i$
$QDIFF_i = DCG_i * W_i$
$QO_i = SOF_i * W_i$
NCU = 0?
NO
YES
WRITE TITLE FOR OUTPUTTING FLOW VALUES FOR WATER QUALITY MODEL
WRITE TITLE AND HEADINGS FOR OUTPUTTING FLOW VALUES FOR WATER QUALITY MODEL
WRITE THE FLOW VALUES FOR WATER QUALITY MODEL
QI_i, QS_i, QPW_i, $QRES_i$, QGI_i, QD_i, QIR_i,
QEF_i, $QTOF_i$, $QGWOF_i$, $QDELGW_i$, QO_i,
$QGFLO_i$, $QDIFF_i$ i = 1,IMT
IT = ITN?
YES
NO
GO TO 1
LL = 0
NPRIT = NPRIT-1
IT = IT + 1
SELECT AND UPDATE ITERATION PARAMETERS AS SPECIFIED BY ISENS
GO TO 998

Figure G-2. Continued.

Table G-1. **Notation used in the computer program of the hydrologic mass balance model.**

Symbol	Description
AC(J)	Area of cropland in crop J (acres)
AC2(J)	Area of wetland in phreatophyte J(acres)
ACU	Actual cropland consumptive use (acre-ft)
ACU1	Label for ACU
AGSC(I,J)	Growth stage coefficient for crop J during month I (dimensionless)
AGW	Root zone storage addition to interflow groundwater storage vector (acre-ft)
AGW1	Label for AGW
ASMS	Accumulated cropland soil moisture storage vector (acre-ft)
ASMS1	Label for ASMS
ASMS(1)	Initial soil moisture storage (acre-ft)
AWLCU	Actual wetland consumptive use vector (acre-ft)
AWLCU1	Label for AWLCU
AWLSM	Accumulated wetland soil moisture storage (acre-ft)
AWLSM1	Label for AWLSM
AWLSM(1)	Initial wetland soil moisture storage (acre-ft)
BCF	Label for Blaney-Criddle "F"
CC	Precipitation adjusting coefficient for cropland (dimensionless)
CD	Agricultural diversions (acre-ft)
CD1	Label for CD
CPR	Reservoir precipitation adjusting coefficient (dimensionless)
CROP(J)	Label for crop J
CT	Temperature adjusting coefficient (dimensionless)
CV	Conversion factor for changing acre-ft/day to cfs (43560/86400)
CW	Pecipitation adjusting coefficient for wetland (dimensionless)
DCG	Difference between computed and gaged surface outflow vector (acre-ft)
DCG1	Label for DCG
DEF	Cropland consumptive use deficit (acre-ft)
DEF1	Label for DEF
DELGW	Change in groundwater storage (acre-ft)
DELGW1	Label for DELGW
DGW	Interflow additions to groundwater storage (acre-ft)
DGW1	Label for DGW
DGX	Yearly addition to groundwater (acre-ft)
DRES	Change in reservoir storage (acre-ft)
DRES1	Label for DRES
DSC	Cropland snow storage added (acre-ft)
DSC1	Label for DSC
DSW	Wetland snow storage added (acre-ft)
DSW1	Label for DSW
DWRZ	Diverted water into cropland root zone storage (acre-ft)
DWRZ1	Label for DWRZ
EFCV	Conveyance efficiency of agricultural diversions (dimensionless)
EFOF	Farm irrigation efficiency (dimensionless)
EKGW	Decay constant for interflow groundwater (dimensionless)
EKGW2	EKGW + 2
EKS	Decay constant for snowmelt ($^{\circ}F^{-1}$)
EKT	Blaney-Criddle temperature coefficient
EMI	Municipal and industrial consumptive use (acre-ft)
EMI1	Label for EMI
EMID	Municipal and industrial diversion (acre-ft)
EMID1	Label for EMID
EMIR	Municipal and industrial return flow vector (acre-ft)
EMIR1	Label for EMIR
ENCRMT	Incrementing value or constant associated with the iteration parameter (same dimension as parameter)
ERR	Sum of squared differences between measured and computed surface outflow vector $(\text{acre-ft})^2$
ERR1	Sum of absolute difference between measured and computed surface outflow vector (acre-ft)
EVAP	Reservoir evaporation (acre-ft)
EVAP1	Label for EVAP
EXPO	Surfaces export (acre-ft)
EXPO1	Label for EXPO
F	Blaney-Criddle 'F' vector
GFLO	Gaged surface outflow (acre-ft)
GFLO1	Label for GFLO
GIN	Total inflow to interflow groundwater storage vector (acre-ft)
GWC	Minimum groundwater discharge from interflow storage (acre-ft)
GWCAP	Interflow storage capacity (acre-ft)
GWIN	Subsurface unmeasured inflow (acre-ft)
GWIN1	Label for GWIN
GWOF	Measured groundwater outflow (acre-ft)
GWOF1	Label for GWOF
GWRT	Cropland groundwater return flow (acre-ft)
GWRT1	Label for GWRT
GWTS	Groundwater to surface (acre-ft)
GWTS1	Label for GWTS
GWWL	Wetland addition to groundwater vector (acre-ft)
IDSENS	Label of parameter selected for iteration
IG	Number of time increments selected for delay of interflow groundwater
IM	Time increments per year (12)
ISENS	Code specification for the iteration parameter
ITN	Number of iteration desired
LTP	Print option selected during iteration
LYR	Label for years being simulated
MBC	Option specification for consumptive use model
NAME	Descriptive name for the area being simulated (label)

Table G-1. Continued.

NCD	Number of agricultural diversions
NCU	Print option for detailed consumptive use output
NC1	Number of agricultural crop classifications
NC2	Number of phreatophytes classifications
NEXPO	Number of exports
NGFLO	Number of measured surface outflows
NGWOF	Number of measured or estimated groundwater outflows
NMI	Number of municipal and industrial consumptive uses
NMID	Number of municipal and industrial diversions
NPR	Print option for input data
NPRIT	Number of initial data printouts desired during iteration
NPW	Number of pumps
NQO	Print option for obtaining values needed for water quality model in cfs
NRES	Number of reservoirs in the system
NRIF	Number of measured surface inflows (main stem primarily)
NSIMP	Number of measured surface imports
NTIF	Number of unmeasured ground and surface water inflows
NYR	Number of years to be simulated
PAC1(J)	Proportion of cropland in crop J
PAC2(J)	Proportion of wetland in phreatophyte J
PCL	Cropland precipitation (inches)
PCL1	Label for PCL
PCU	Cropland potential consumptive unit use array (acre-ft)
PCUU	Cropland potential consumptive unit use array (inches)
PDH(I)	Proportion of daylight hours for month I
PGSC(I,J)	Growth stage coefficient for phreatophyte J during month I
PHR(J)	Label for phreatophyte J
PKGW	Ratio of yearly groundwater outflow to yearly addition to groundwater
PREC	Unadjusted monthly precipitation (inches)
PREC1	Label for PREC
PRES	Reservoir precipitation (inches)
PRES1	Label for PRES
PW	Pumped water (acre-ft)
PW1	Label for PW
PWL	Wetland precipitation (inches)
PWL1	Label for PWL
QCD	Cropland diversions (cfs)
QCD1	Label for QCD
QD	Total diversions (cfs)
QD1	Label for QD
QDELGW	Change in groundwater storage (average cfs for time period specified in output)
QDELGW1	Label for QDELGW
QDIFF	Difference between computed and gaged surface outflow (cfs)
QDIFF1	Label for QDIFF
QEF	Municipal and industrial return flow (cfs)
QEF1	Label for QEF
QEX	Export vector (cfs)
QEX1	Label for QEX
QGFLO	Gaged urface outflow vector (cfs)
QGFLO1	Label for QGFLO
QGI	Groundwater to surface vector (cfs)
QGI1	Label for QGI
QGWOF	Groundwater outflow vector (cfs)
QGWOF1	Label for QGWOF
QI	Measured surface inflow in main channel vector (cfs)
QI1	Label for QI
QIR	Cropland surface return flow vector (cfs)
QIR1	Label for QIR
QMID	Municipal and industrial diversion vector (cfs)
QMID1	Label for QMID
QO	Computed surface outflow vector (cfs)
QO1	Label for QO
QPW	Pumped water vector (cfs)
QPW1	Label for QPW
QRES	Change in reservoir storage vector (cfs)
QRES1	Label for QRES
QS	Unmeasured surface inflow to main channel vector (cfs)
QS1	Label for QS
QTOF	TOF vector converted (cfs)
QTOF1	Label for QTOF
RES	Reservoir storage (acre-ft)
RES1	Label for RES
RESF	Initial reservoir storage (acre-ft)
RIF	Measured surface inflow in the main stem (acre-ft)
RIF1	Label for RIF
RTFLO	Cropland return flow (acre-ft)
RTFLO1	Label for RTFLO
RTK(I)	Cropland groundwater return flow coefficient for month I
RZD	Root zone depth (feet)
SGW	Accumulated interflow groundwater storage (acre-ft)
SGW1	Label for SGW
SGW(1)	Initial interflow groundwater storage (acre-ft)
SIMP	Measured surface imports (acre-ft)
SIMP1	Label for SIMP
SINT	Interflow groundwater storage transferred to surface (acre-ft)
SINT1	Label for SINT
SKW(I)	Initialization coefficients for interflow groundwater storage for compartment I
SMA	Cropland snowmelt (acre-ft)
SMA1	Label for SMA
SMC	Cropland soil moisture capacity (acre-ft)
SMC1	Water holding capacity of the root zone (inches/foot)
SMS	Change in cropland soil moisture storage vector (acre-ft)
SMS1	Label for SMS
SMW	Wetland snowmelt (acre-ft)
SMW1	Label for SMW
SOF	Computed surface outflow vector (acre-ft)

Table G-1. Continued.

SOF1	Label for SOF
SPCU	Sum of cropland potential consumptive use (acre-ft)
SPCU1	Label for SPCU
SRTF	Cropland surface return flow (acre-ft)
SRTF1	Label for SRTF
SSC	Cropland accumulated snow storage at beginning of month (acre-ft) vector
SSC1	Label for SSC
SSO	Initial snow storage (inches)
SSW(I)	Wetland accumulated snow storage at beginning of month I (acre-ft)
STA	Six character code for name for the area being simulated
STA1	Six character code for name for the area being simulated
STA2	Six character code for name for the area being simulated
STFK(I)	Surface unmeasured inflow coefficient for month I
STIF	Surface unmeasured inflow (acre-ft)
STIF1	Label for STIF
STW(I)	Interflow groundwater in compartment I of interflow storage (acre-ft)
SWL	Interflow surface supply to wetland (acre-ft)
SWL1	Label for SWL
SWLCU	Sum of wetland potential consumptive use (acre-ft)
SWLCU1	Label for SWLCU
SWCK(I)	Interflow supply to wetland coefficient for month I (acre-ft)
TAC	Cropland area (acres)
TARES	Total area of reservoirs (acres)
TAVE	Adjusted temperature (°F)
TAWC	Wetland area (acres)
TEMP	Unadjusted monthly temperature (°F)
TEMP1	Label for TEMP
TGWA	Total addition to groundwater storage vector (acre-ft)
TGWA1	Label for TGWA
TIF	Unmeasured surface and subsurface inflow (acre-ft)
TIF1	Label for TIF
TKGW	Proportion of total outflow passing ungaged below the gage control as interflow or groundwater flow (acre-ft)
TOF	Total outflow plus change in groundwater storage vector (acre-ft)
TOF1	Label for TOF
TP	Threshold temperature for snow storage (°F)
TRI	Interflow groundwater in last compartment of interflow storage (acre-ft)
TSM	Threshold temperature for snowmelt (°F)
TSRZ	Total supply to cropland root zone storage (acre-ft)
TSRZ1	Label for TSRZ
TSWL	Total supply to wetland (acre-ft)
TSWL1	Label for TSWL
USW	Total available surface water vector (acre-ft)
USW1	Label for USW
VAR1	Labels for months and year for column headings of output
WEVAP	Reservoir evaporation vector (inches)
WGSC	Pseudo growth stage coefficient vector for reservoir water
WGWK	Decay constant for wetland groundwater outflow
W(I)	Conversion factor for changing acre-ft/month to cfs for month I
WLAGW	Wetland addition to groundwater storage (acre-ft)
WLAGW1	Label for WLAGW
WLCU	Wetland potential consumptive unit use array (acre-ft)
WLCUU	Wetland potential consumptive unit use array (inches)
WLDEF	Wetland soil moisture storage deficit vector (acre-ft)
WLDEF1	Label for WLDEF
WLSFC	Wetland surface return flow (acre-ft)
WLSFC1	Label for WLSFC
WLSM	Change in wetland soil moisture storage (acre-ft)
WLSM1	Label for WLSM
WLSMC	Wetland soil moisture capacity (acre-ft)
WTR	Label for reservoir water

Table G-2. Preparation instructions for Group I input cards (20 cards; output label designations).

Card	Col	Format	Name	Definition
1	1-25	5A5	R1F1	Measured inflow
	26-50	5A5	T1F1	Unmeasured inflow
	51-75	5A5	RES1	Reservoir storage
2	1-25	5A5	DRES1	Change in reservoir
	26-50	5A5	USW1	Useable surface water
	51-75	5A5	CD1	Cropland diversions
3	1-25	5A5	DWRZ1	Diverted water to cropland root zone storage
	26-50	5A5	PW1	Pumped water
	51-75	5A5	GW1N1	Groundwater inflow
4	1-25	5A5	PCL1	Cropland precipitation
	26-50	5A5	TSRZ1	Root zone supply
	51-75	5A5	SMS1	Root zone supply-P.C.U.
5	1-25	5A5	ASMS1	Accumulated cropland soil moisture
	26-50	5A5	SPCU1	Cropland potential consumptive use
	51-75	5A5	DEF1	Consumptive use deficit
6	1-25	5A5	ACU1	Actual cropland consumptive use
	26-50	5A5	PREC1	Input precipitation
	51-75	5A5	RTFLO1	Cropland return flow
7	1-25	5A5	EMI1	Municipal and industrial use
	26-50	5A5	SWLI	Interflow supply to wetland
	51-75	5A5	PWL1	Wetland precipitation
8	1-25	5A5	SWLCU1	Wetland consumptive use
	26-50	5A5	EXPO1	Exports
	51-75	5A5	SOF1	Surface outflow
9	1-25	5A5	TEMP1	Input temperature
	26-50	5A5	BCF	Blaney-Criddle "F"
	51-75	5A5	DELGW1	Change in GW storage
10	1-25	5A5	SSC1	Accumulated snow storage
	26-50	5A5	SMA1	Snow melt on cropland
	51-75	5A5	DSC1	Snow storage added to cropland
11	1-25	5A5	AGW1	Cropland addition to interflow
	26-50	5A5	SGW1	Accumulated interflow
	51-75	5A5	DGW1	Interflow added to groundwater
12	1-25	5A5	TOF1	Outflow and change in groundwater storage
	26-50	5A5	GFLO1	Gaged surface outflow
	51-75	5A5	DCG1	Difference between computed and gaged surface outflow

Table G-2. Continued.

13	1-25	5A5	GWOF1	Groundwater outflow
	26-50	5A5	GWRT1	Cropland groundwater return flow
	51-75	5A5	SRTF1	Cropland surface return flow
14	1-25	5A5	DSW1	Snow storage on wetland
	26-50	5A5	SMW1	Snow melt on wetland
	51-75	5A5	TGWA1	Total addition to groundwater storage
15	1-25	5A5	PRES1	Reservoir precipitation
	26-50	5A5	EVAP1	Reservoir evaporation
	51-75	5A5	WLSM1	Wetland supply-potential wetland consumptive use
16	1-25	5A5	AWLCU1	Actual wetland consumptive use
	26-50	5A5	AWLSM1	Accumulated wetland soil moisture
	51-75	5A5	WLDEF1	Wetland consumptive use deficit
17	1-25	5A5	WLAGW1	Wetland addition to groundwater
	26-50	5A5	TSWL1	Total supply to the wetland
	51-75	5A5	SIMP1	Important surface water
18	1-25	5A5	EMID1	Municipal and industrial diversions
	26-50	5A5	EMIR1	Municipal and industrial return flow
	51-75	5A5	WLSFC1	Wetland surface outflow
19	1-25	5A5	STIF1	Unmeasured surface inflow
	26-50	5A5	GWTS1	GW to surface water
	51-75	5A5	SINT1	Interflow to surface water
20	1-75	13A6	VAR1	13 time increment (months) labels heading their respective columns in the budget output

Table G-3. Preparation instructions for Group II input cards (8 cards; control and parameter initialization).[a]

Card	Col	Format	Name	Definition
1	1-80	20A4	NAME	Area name and identification designation
2	1-06	A6	STA	Area identification (mnemonic)
	7-08	I2	NYR	No. of years ≤ 30
	9-10	I2	IM	Time increments per year $1 \leq IM \leq 12$
	11-12	I2	NC1	No. of agricultural crops ≤ 13
	13-14	I2	NC2	No. of phreatophytes ≤ 9
	15-16	I2	MBC	0(zero) value for Blaney-Criddle method of CU calculation 1(one) for modified Blaney-Criddle method
	17-18	I2	NPR	1 for printing input data 0 for suppressing printing of input data
	19-20	I2	NRIF	No. of measured inflows
	21-22	I2	NCD	No. of cropland diversions
	23-24	I2	NPW	No. of wells (pumped water measurement)
	25-26	I2	NMID	No. of municipal & industrial use diversions
	27-28	I2	NMI	No. of municipal & industrial uses
	29-30	I2	NTIF	No. of unmeasured surface inflows
	31-32	I2	NIMP	No. of surface imports
	33-34	I2	NRES	No. of reservoirs
	35-36	I2	NEXPO	No. of measured surface exports
	37-38	I2	NGFLO	No. of gaged outflows
	39-40	I2	NGWOF	No. of groundwater outflows
	41-42	I2	IG	No. of time increments for delay in transitional groundwater storage ≤ IM
	43	I1	NCU	1 for printing consumptive use and interflow storage detail 0 for suppressing above printing
	44-46	F3.2	EFOF	Farm irrigation efficiency
	47-49	F3.2	EFCV	Conveyance efficiency for water diverted to cropland
	50-54	F5.3	CC	Adjusting coefficient for cropland precipitation
	55-59	F5.3	CW	Adjusting coefficient for wetland precipitation
	60-64	F5.3	CT	Adjusting coefficient for cropland temperature
	65-68	F4.3	EKGW	Decay constant for interflow added to groundwater
	69-72	F4.3	EKS	Decay constant for snowmelt
	73-76	F4.1	TP	Threshold temperature for snow storage
	77-80	F4.1	TSM	Threshold temperature for snow

Table G-3. Continued.

Card	Col	Format	Name	Definition
3	1-06	A6	STA1	Area identification
	7-14	F8.0	TAC	Area of cropland in acres
	15-22	F8.0	TAWL	Area of wetland in acres
	23-30	F8.0	RESF	Reservoir storage at beginning of period in acre-feet
	31-36	F6.0	$ASMS_{1,1}$	Initial value of soil moisture storage in acre-feet
	37-41	F5.2	RZD	Root zone depth in feet
	42-46	F5.2	SMC1	Water holding capacity of root zone in inches/ft.
	47-51	F5.2	SSO	Initial value of snow storage in inches
	52-59	F8.0	$SGW_{1,1}$	Initial value of interflow storage in acre-feet
	60-67	F8.0	GWC	Minimum discharge from interflow in acre-feet
	68-72	F5.3	TKGW	Proportion of outflow going under the gage as groundwater outflow
	73-80	F8.0	GWCAP	Capacity of interflow storage
4	1-6	A6	STA2	Area identification
	7-8	I2	NQO	Print option for water quality hydrology output if non zero (If > 1 then only those values used by WAQUAL as output)
	11-15	F5.3	CPR	Adjusting coefficient for reservoir precipitation
	16-20	F5.3	WGWK	Decay constant for wetland GW outflow
	21-30	F10.0	TARES	Total area of reservoirs in acres
	31-40	F10.0	$AWLSM_{1,1}$	Initial value of wetland soil moisture storage in acre-feet
	41-50	F10.0	WLSMC	Wetland soil moisture capacity in acre-feet

If selective iteration is desired when using HYDRO, then the following variables must be supplied on card 4. If supplied they are ignored by BUDGET.

Card	Col	Format	Name	Definition
4	51-56	A6	IDSENS	Identification label of the parameter selected for iteration
	57-58	I2	NPRIT	Number of input data printouts desired after initial printout if $NPR \neq 0$
	59-60	I2	ISENS	Code specification for the parameter selected for iteration. See Table A-5 for valid specification codes.
	61-62	I2	LTP	Prints entire BUDGET without iteration information. Prints entire BUDGET with iteration information. Prints only last with 5 line 7 Budget.

Table G-3. Continued.

Card	Col	Format	Name	Definition
	63-65	I3	ITN	Number of iterations desired
	66-75	F10.0	ENCRMT	Incrementing interval or constants associated with the parameter selected for iteration.
5	Initialization coefficients for the interflow storage (STW) punched in FORMAT(14X,12F5.3). This card is needed only when IG≠0.			
6	Cropland groundwater return flow coefficients (RTK) punched in FORMAT(14X,12F5.3).			
7	Unmeasured surface inflow coefficients (STFK) punched in FORMAT(14X,12F5.3).			
8	Supply to wetland coefficients (SWLK) punched in FORMAT(14X,12F5.3).			

[a] All unmeasured values are initial estimates, modified by trial as validation proceeds.

Table G-4. Preparation instructions for Group III input cards for data vectors (number of cards is dependent upon amount of data used).

Card[a]	
1	Proportion of daylight hours (PDH) punched in FORMAT (14X,12F5.4).
2	Proportion of crop area (AC1) FORMAT (10X,13F5.3).
2_1 to 2_{NC1}	Crop label and growth stage coefficients (CROP; AGSC) punched in FORMAT (8X,A6,12F5.3). Include only if NC1 > 0.
3	Proportion of phreatophyte area (AC2) punched in FORMAT (10X,13F5.3).
3_1 to 3_{NC2}	Phreatophyte label and growth stage coefficients (PHR;PGSC) punched in FORMAT (98X,A6,12F5.2). Include only if NC2 > 0.
4	Label and use coefficients for reservoir water (WTR;WGSC) punched in FORMAT (8X,A6,12F5.2). Include only if NRES > 0.
5	Label for years, mean, and standard deviation punched in FORMAT (10X,14A5). (Should have NYR+2 labels punched).
6	FORMAT specification for reading RIF vector (include only if NRIF > 0).
6_1 to 6_{NRIF}	Measured inflow data in acre-ft.
7	FORMAT specification for reading SIMP vector (include only if NIMP > 0).
7_1 to 7_{NIMP}	Surface input in acre-ft.
8	FORMAT specification for reading CD vector (include only if NCD > 0).
8_1 to 8_{NCD}	Cropland diversion data in acre-ft.
9	FORMAT specification for reading PW vector (include only if NPW > 0).
9_1 to 9_{NPW}	Pumped water data in acre-ft.
10	FORMAT specification for reading PREC vector (must be included).
10_1	Precipitation data in inches.
11	FORMAT specification for reading TEMP vector (must be included).
11_1	Temperature data in F.
12	FORMAT specification for reading EMID vector (include only if NMID > 0).
12_1 to 12_{NIMD}	Municipal & industrial diversion data in acre-ft
13	FORMAT specification for reading EMI vector (include only if NMI >0).
13_1 to 13_{NMI}	Municipal and industrial use (depletion) data in acre-ft.
14	FORMAT specification for reading TIF vector (include only if NTIF > 0).
14_1 to 14_{NTIF}	Unmeasured inflow data in acre-ft.
15	FORMAT specification for reading RES vector (include only if NRES > 0).
15_1 to 15_{NRES}	Reservoir storage at end of month in acre-ft.
16	FORMAT specification for reading EXPO vector (include only if NEXPO> 0).
16_1 to 16_{NEXPO}	Measured export data in acre-ft.
17	FORMAT specification for reading GFLO vector (include only if NGFLO > 0).
17_1 to 17_{NFGLO}	Gaged outflow data in acre-ft.
18	FORMAT specification for reading GWOF vector (include only if NGWOF > 0).
18_1 to 18_{NGWOF}	Groundwater outflow data in acre-ft.

[a] Subscripts refer to number of cards used for a given vector.

Table G-5. Iteration specification codes (ISENS) that may be selected for HYDRO.

Code	Parameter Affected	Description
1	IG&SKW	Change time increment of interflow GW storage delay by ENCRMT each iteration. Specification of this option requires reading ITN-2 cards designing values to the interflow GW coefficient (SKW_1) following the regular Group III data cards specified hereafter--FORMAT for reading SKW is (14X,12F5.3).
2	EFOF	Change farm irrigation application efficiency by ENCRMT each iteration.
3	SGW(1)& GWCAP	Change interflow GW cap by ENCRMT each iteration and keep initial condition of interflow storage at capacity.
4	CC	Change cropland precipitation adjustment coefficient by ENCRMT each iteration.
5	CW	Change wetland precipitation adjustment coefficient by ENCRMT each iteration.
6	CT	Change temperature adjustment coefficient by ENCRMT each iteration.
7	EKGW	Change exponential decay constant for interflow storage added to GW by ENCRMT each iteration.
8	EKS	Change exponential decay constant for snowmelt by ENCRMT each iteration.
9	TP	Change threshold temperature for snow storage by ENCRMT each iteration.
10	TSM	Change threshold temperature for snowmelt by ENCRMT each iteration.
11	ASMS(1)	Change initial cropland soil moisture storage by ENCRMT each iteration.
12	RZD	Change cropland root zone depth by ENCRMT each iteration.
13	SMC1	Change root zone water holding capacity by ENCRMT each iteration.
14	SSO	Change initial snow storage by ENCRMT each iteration.
15	SGW(1)	Change initial interflow storage by ENCRMT each iteration.
16	GWC	Change minimum GW discharge from interflow storage by ENCRMT each iteration.
17	TKGW	Change proportion of total outflow assumed to be GW outflow by ENCRMT each iteration.
18	GWCAP	Change capacity of interflow storage by ENCRMT each iteration.
19	CPR	Change adjustment coefficient for reservoir precipitation by ENCRMT each iteration.
20	WGWK	Change exponential decay constant for wetland soil moisture added to GW by ENCRMT each iteration.
21	AWLSM(1)	Change initial wetland soil moisture storage by ENCRMT each iteration.
22	WLSMC	Change wetland soil moisture capacity by ENCRMT each iteration.
23	RTK_i	Change cropland groundwater return flow coefficients by reading in a new set each iteration. Require ITN-1 cards trailing the regular Group III data deck. Read FORMAT for RTK is (14X,12F5.3).
24	AWLSM(1) WLSMC	Change wetland soil moisture capacity by ENCRMT each iteration and keep initial condition at WLSMC.
25	$STFK_i$	Change inflow coefficients by reading a new set of each iteration. Requires ITN-1 cards trailing regular Group III data deck punched in FORMAT (14X,12F5.3).
26	$SWLK_i$	Change wetland supply coefficients by reading a new set each iteration. Require ITN-1 cards trailing the regular Group III data deck punched in FORMAT (14X,12F5.3).

Table G-5. Continued.

Code	Parameter Affected	Description
27	TIF	Change amount of unmeasured surface inflow by a multiplication factor increased by ENCRMT each iteration.
28	GWOF	Change amount of groundwater outflow by a multiplicative factor increased by ENCRMT each iteration.
29	PREC	Change unadjusted input precipitation by reading a new set of values each iteration punched in FORMAT (14X,13F5.2). This option requires that ITN-1 PREC cards trail the Group III input data.
30	TEMP	Change unadjusted temperature by reading a new set of values each iteration punched in FORMAT (14X,13F5.1). This option requires that ITN-1 TEMP cards trail the regular Group III input data.
31	PAC1	Change percent distribution of cropland areas by reading a new set of values each iteration. Input FORMAT is (10X,14F5.3). This option requires ITN-1 PAC1 cards trail the regular Group III input data.
32	PAC2	Change present distribution of wetland areas by reading a new set of values each iteration. Input FORMAT is (10X,14F5.3). This option requires ITN-1 PAC2 cards trail the regular Group III input data.

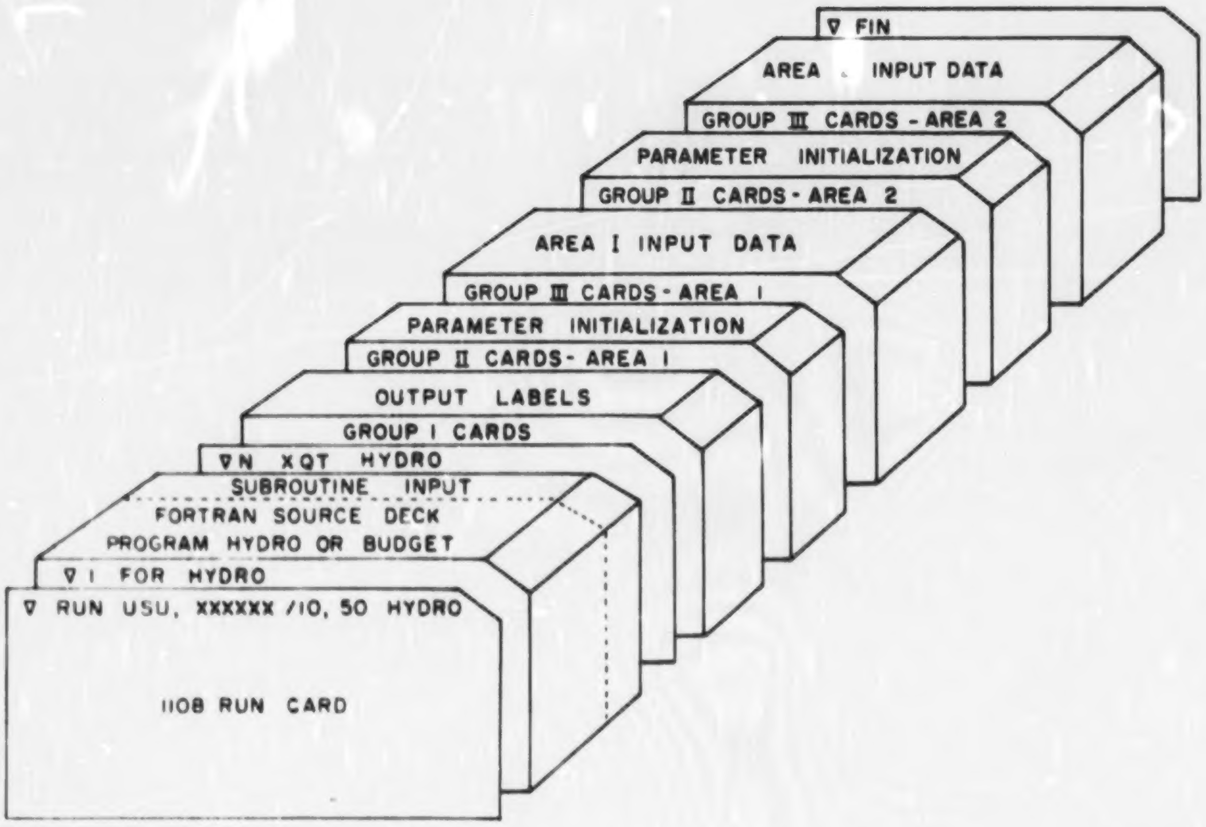
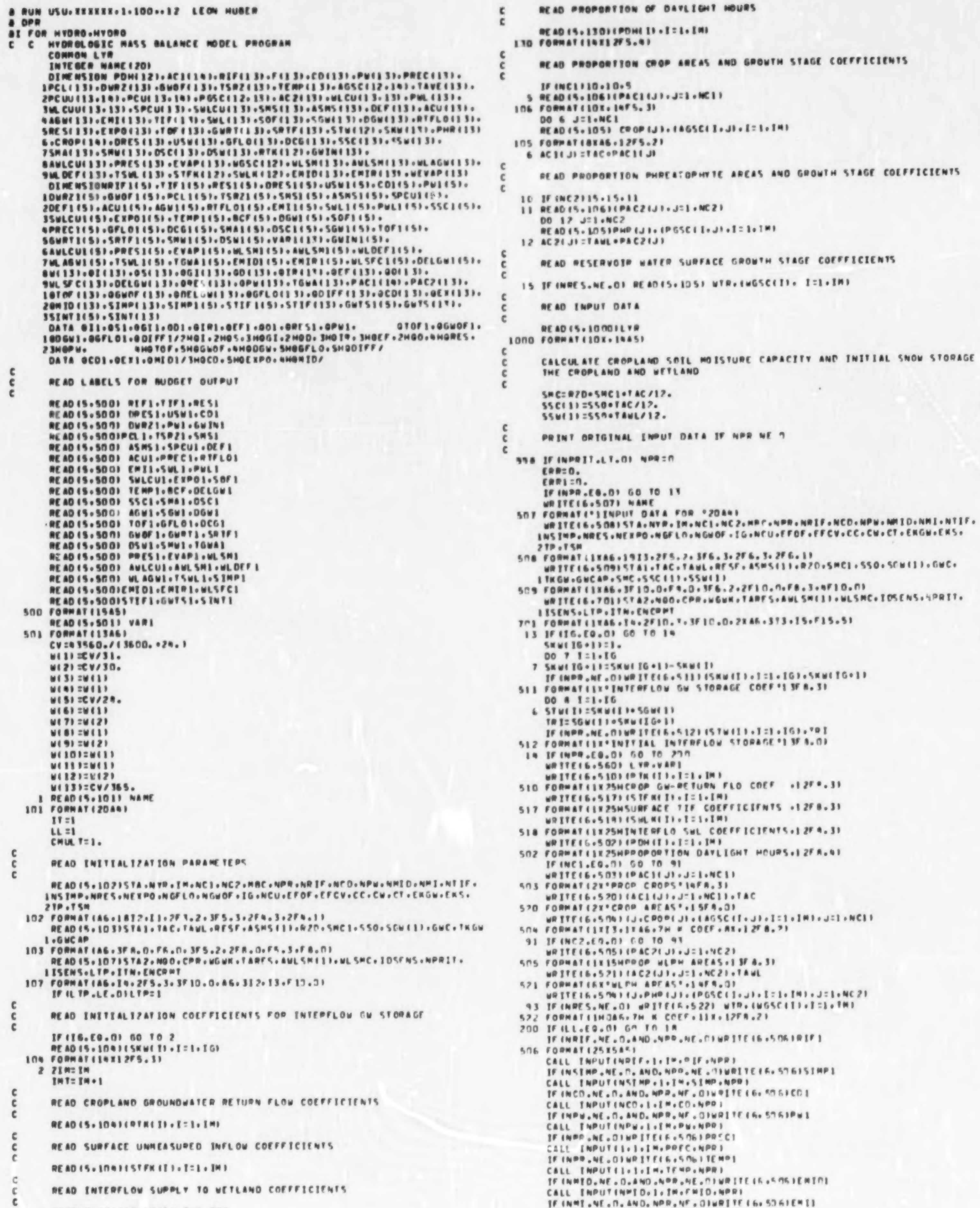

∇ FIN
AREA INPUT DATA
GROUP III CARDS - AREA 2
PARAMETER INITIALIZATION
GROUP II CARDS - AREA 2
AREA I INPUT DATA
GROUP III CARDS - AREA I
PARAMETER INITIALIZATION
GROUP II CARDS - AREA I
OUTPUT LABELS
GROUP I CARDS
∇N XQT HYDRO
SUBROUTINE INPUT
FORTRAN SOURCE DECK
PROGRAM HYDRO OR BUDGET
∇ I FOR HYDRO
∇ RUN USU, XXXXXX /10, 50 HYDRO
1108 RUN CARD

Figure G-3. Deck set-up for running HYDRO or BUDGET.



```
@ RUN USU,XXXXXX,1,100,,12  LEON HUBER
@ OPR
@I FOR HYDRO,HYDRO
C  C  HYDROLOGIC MASS BALANCE MODEL PROGRAM
      COMMON LYR
      INTEGER NAME(20)
      DIMENSION PDH(12),AC1(14),RIF(13),F(13),CD(13),PW(13),PREC(13),
     1PCL(13),DWRZ(13),GWOF(13),TSRZ(13),TEMP(13),AGSC(12,14),TAVE(13),
     2PCUU(13,14),PCU(13,14),PGSC(12,13),AC2(13),WLCU(13,13),PWL(13),
     3WLCUU(13,13),SPCU(13),SWLCU(13),SMS(13),ASMS(13),DEF(13),ACU(13),
     4AGW(13),EMI(13),TIF(13),SWL(13),SOF(13),SGW(13),DGW(13),RTFLO(13),
     5RES(13),EXPO(13),TOF(13),GWRT(13),SRTF(13),STW(12),SKW(13),PHR(13)
     6,CROP(14),DRES(13),USW(13),GFLO(13),DCG(13),SSC(13),SSW(13),
     7SMA(13),SMW(13),DSC(13),DSW(13),RTK(12),GWIN(13),
     8AWLCU(13),PRES(13),EVAP(13),WGSC(12),WLSM(13),AWLSM(13),WLAGW(13),
     9WLDEF(13),TSWL(13),STFK(12),SWLK(12),EMID(13),EMIR(13),WEVAP(13)
      DIMENSIONRIF1(5),TIF1(5),RES1(5),DRES1(5),USW1(5),CD1(5),PW1(5),
     1DWRZ1(5),GWOF1(5),PCL1(5),TSRZ1(5),SMS1(5),ASMS1(5),SPCU1(5),
     2DEF1(5),ACU1(5),AGW1(5),RTFLO1(5),EMI1(5),SWL1(5),PWL1(5),SSC1(5),
     3SWLCU1(5),EXPO1(5),TEMP1(5),BCF(5),DGW1(5),SOF1(5),
     4PREC1(5),GFLO1(5),DCG1(5),SMA1(5),DSC1(5),SGW1(5),TOF1(5),
     5GWRT1(5),SRTF1(5),SMW1(5),DSW1(5),VAR1(13),GWIN1(5),
     6AWLCU1(5),PRES1(5),EVAP1(5),WLSM1(5),AWLSM1(5),WLDEF1(5),
     7WLAGW1(5),TSWL1(5),TGWA1(5),EMID1(5),EMIR1(5),WLSFC1(5),DELGW1(5),
     8W(13),QI(13),QS(13),QGI(13),QD(13),QIR(13),QEF(13),QO(13),
     9WLSFC(13),DELGW(13),QRES(13),QPW(13),TGWA(13),PAC1(14),PAC2(13),
     1QTOF(13),QGWOF(13),QDELGW(13),QGFLO(13),QDIFF(13),QCD(13),QEX(13),
     2QMID(13),SIMP(13),SIMP1(5),STIF1(5),STIF(13),GWTS1(5),GWTS(13),
     3SINT1(5),SINT(13)
      DATA QI1,QS1,QGI1,QD1,QIR1,QEF1,QO1,QRES1,QPW1,      QTOF1,QGWOF1,
     1QDGW1,QGFLO1,QDIFF1/2HQI,2HQS,3HQGI,2HQD,3HQIR,3HQEF,2HQO,4HQRES,
     23HQPW,      4HQTOF,5HQGWOF,4HQDGW,5HQGFLO,5HQDIFF/
      DATA QCD1,QEX1,QMID1/3HQCD,5HQEXPO,4HQMID/
C
C     READ LABELS FOR BUDGET OUTPUT
C
      READ(5,500) RIF1,TIF1,RES1
      READ(5,500) DRES1,USW1,CD1
      READ(5,500) DWRZ1,PW1,GWIN1
      READ(5,500)PCL1,TSRZ1,SMS1
      READ(5,500) ASMS1,SPCU1,DEF1
      READ(5,500) ACU1,PREC1,RTFLO1
      READ(5,500) EMI1,SWL1,PWL1
      READ(5,500) SWLCU1,EXPO1,SOF1
      READ(5,500) TEMP1,BCF,DELGW1
      READ(5,500) SSC1,SMA1,DSC1
      READ(5,500) AGW1,SGW1,DGW1
      READ(5,500) TOF1,GFLO1,DCG1
      READ(5,500) GWOF1,GWRT1,SRTF1
      READ(5,500) DSW1,SMW1,TGWA1
      READ(5,500) PRES1,EVAP1,WLSM1
      READ(5,500) AWLCU1,AWLSM1,WLDEF1
      READ(5,500) WLAGW1,TSWL1,SIMP1
      READ(5,500)EMID1,EMIR1,WLSFC1
      READ(5,500)STIF1,GWTS1,SINT1
  500 FORMAT(15A5)
      READ(5,501) VAR1
  501 FORMAT(13A6)
      CV=43560./(3600.*24.)
      W(1)=CV/31.
      W(2)=CV/30.
      W(3)=W(1)
      W(4)=W(1)
      W(5)=CV/28.
      W(6)=W(1)
      W(7)=W(2)
      W(8)=W(1)
      W(9)=W(2)
      W(10)=W(1)
      W(11)=W(1)
      W(12)=W(2)
      W(13)=CV/365.
    1 READ(5,101) NAME
  101 FORMAT(20A4)
      IT=1
      LL=1
      CMULT=1.
C
C     READ INITIALIZATION PARAMETERS
C
      READ(5,102)STA,NYR,IM,NC1,NC2,MBC,NPR,NRIF,NCD,NPW,NMID,NMI,NTIF,
     1NSIMP,NRES,NEXPO,NGFLO,NGWOF,IG,NCU,EFOF,EFCV,CC,CW,CT,EKGW,EKS,
     2TP,TSM
  102 FORMAT(A6,18I2,I1,2F3.2,3F5.3,2F4.3,2F4.1)
      READ(5,103)STA1,TAC,TAWL,RESF,ASMS(1),RZD,SMC1,SSO,SGW(1),GWC,TKGW
     1,GWCAP
  103 FORMAT(A6,3F8.0,F6.0,3F5.2,2F8.0,F5.3,F8.0)
      READ(5,107)STA2,NOO,CPR,WGWK,TARES,AWLSM(1),WLSMC,IDSENS,NPRIT,
     1ISENS,LTP,ITN,ENCRMT
  107 FORMAT(A6,I4,2F5.3,3F10.0,A6,3I2,I3,F10.0)
      IF(LTP.LE.0)LTP=1
C
C     READ INITIALIZATION COEFFICIENTS FOR INTERFLOW GW STORAGE
C
      IF(IG.EQ.0) GO TO 2
      READ(5,104)(SKW(I),I=1,IG)
  104 FORMAT(14X12F5.3)
    2 ZIM=IM
      IMT=IM+1
C
C     READ CROPLAND GROUNDWATER RETURN FLOW COEFFICIENTS
C
      READ(5,104)(RTK(I),I=1,IM)
C
C     READ SURFACE UNMEASURED INFLOW COEFFICIENTS
C
      READ(5,104)(STFK(I),I=1,IM)
C
C     READ INTERFLOW SUPPLY TO WETLAND COEFFICIENTS
C
      READ(5,104)(SWLK(I),I=1,IM)
C
C     READ PROPORTION OF DAYLIGHT HOURS
C
      READ(5,130)(PDH(I),I=1,IM)
  130 FORMAT(14X12F5.4)
C
C     READ PROPORTION CROP AREAS AND GROWTH STAGE COEFFICIENTS
C
      IF(NC1)10,10,5
    5 READ(5,106)(PAC1(J),J=1,NC1)
  106 FORMAT(10X,14F5.3)
      DO 6 J=1,NC1
      READ(5,105) CROP(J),(AGSC(I,J),I=1,IM)
  105 FORMAT(8XA6,12F5.2)
    6 AC1(J)=TAC*PAC1(J)
C
C     READ PROPORTION PHREATOPHYTE AREAS AND GROWTH STAGE COEFFICIENTS
C
   10 IF(NC2)15,15,11
   11 READ(5,106)(PAC2(J),J=1,NC2)
      DO 12 J=1,NC2
      READ(5,105)PHP(J),(PGSC(I,J),I=1,IM)
   12 AC2(J)=TAWL*PAC2(J)
C
C     READ RESERVOIR WATER SURFACE GROWTH STAGE COEFFICIENTS
C
   15 IF(NRES.NE.0) READ(5,105) WTR,(WGSC(I), I=1,IM)
C
C     READ INPUT DATA
C
      READ(5,1000)LYR
 1000 FORMAT(10X,14A5)
C
C     CALCULATE CROPLAND SOIL MOISTURE CAPACITY AND INITIAL SNOW STORAGE
C     THE CROPLAND AND WETLAND
C
      SMC=RZD*SMC1*TAC/12.
      SSC(1)=SSO*TAC/12.
      SSW(1)=SSO*TAWL/12.
C
C     PRINT ORIGINAL INPUT DATA IF NPR NE 0
C
  998 IF(NPRIT.LT.0) NPR=0
      ERR=0.
      ERR1=0.
      IF(NPR.EQ.0) GO TO 13
      WRITE(6,507) NAME
  507 FORMAT('1INPUT DATA FOR '20A4)
      WRITE(6,508)STA,NYR,IM,NC1,NC2,MBC,NPR,NRIF,NCD,NPW,NMID,NMI,NTIF,
     1NSIMP,NRES,NEXPO,NGFLO,NGWOF,IG,NCU,EFOF,EFCV,CC,CW,CT,EKGW,EKS,
     2TP,TSM
  508 FORMAT(1XA6,19I3,2F5.2,3F6.3,2F6.3,2F6.1)
      WRITE(6,509)STA1,TAC,TAWL,RESF,ASMS(1),RZD,SMC1,SSO,SGW(1),GWC,
     1TKGW,GWCAP,SMC,SSC(1),SSW(1)
  509 FORMAT(1XA6,3F10.0,F9.0,3F6.2,2F10.0,F8.3,4F10.0)
      WRITE(6,701)STA2,NOO,CPR,WGWK,TARES,AWLSM(1),WLSMC,IDSENS,NPRIT,
     1ISENS,LTP,ITN,ENCRMT
  701 FORMAT(1XA6,I4,2F10.3,3F10.0,2XA6,3I3,I5,F15.5)
   13 IF(IG.EQ.0) GO TO 14
      SKW(IG+1)=1.
      DO 7 I=1,IG
    7 SKW(IG+1)=SKW(IG+1)-SKW(I)
      IF(NPR.NE.0)WRITE(6,511)(SKW(I),I=1,IG),SKW(IG+1)
  511 FORMAT(1X'INTERFLOW GW STORAGE COEF'13F8.3)
      DO 8 I=1,IG
    8 STW(I)=SKW(I)*SGW(1)
      TRI=SGW(1)*SKW(IG+1)
      IF(NPR.NE.0)WRITE(6,512)(STW(I),I=1,IG),TRI
  512 FORMAT(1X'INITIAL INTERFLOW STORAGE'13F8.0)
   14 IF(NPR.EQ.0) GO TO 200
      WRITE(6,560) LYR,VAR1
      WRITE(6,510)(RTK(I),I=1,IM)
  510 FORMAT(1X25HCROP GW-RETURN FLO COEF  ,12F8.3)
      WRITE(6,517)(STFK(I),I=1,IM)
  517 FORMAT(1X25HSURFACE TIF COEFFICIENTS ,12F8.3)
      WRITE(6,518)(SWLK(I),I=1,IM)
  518 FORMAT(1X25HINTERFLO SWL COEFFICIENTS,12F8.3)
      WRITE(6,502)(PDH(I),I=1,IM)
  502 FORMAT(1X25HPROPORTION DAYLIGHT HOURS,12F8.4)
      IF(NC1.EQ.0) GO TO 91
      WRITE(6,503)(PAC1(J),J=1,NC1)
  503 FORMAT(2X'PROP CROPS'14F8.3)
      WRITE(6,520)(AC1(J),J=1,NC1),TAC
  520 FORMAT(2X'CROP AREAS',15F8.0)
      WRITE(6,504)(J,CROP(J),(AGSC(I,J),I=1,IM),J=1,NC1)
  504 FORMAT(1XI3,1XA6,7H K COEF,8X,12F8.2)
   91 IF(NC2.EQ.0) GO TO 93
      WRITE(6,505)(PAC2(J),J=1,NC2)
  505 FORMAT(1X15HPROP WLPH AREAS,13F8.3)
      WRITE(6,521)(AC2(J),J=1,NC2),TAWL
  521 FORMAT(6X'WLPH AREAS',14F8.0)
      WRITE(6,504)(J,PHP(J),(PGSC(I,J),I=1,IM),J=1,NC2)
   93 IF(NRES.NE.0) WRITE(6,522) WTR,(WGSC(I),I=1,IM)
  522 FORMAT(1H0A6,7H K COEF,11X,12F8.2)
  200 IF(LL.EQ.0) GO TO 18
      IF(NRIF.NE.0.AND.NPR.NE.0)WRITE(6,506)RIF1
  506 FORMAT(25X5A5)
      CALL INPUT(NRIF,1,IM,RIF,NPR)
      IF(NSIMP.NE.0.AND.NPR.NE.0)WRITE(6,506)SIMP1
      CALL INPUT(NSIMP,1,IM,SIMP,NPR)
      IF(NCD.NE.0.AND.NPR.NE.0)WRITE(6,506)CD1
      CALL INPUT(NCD,1,IM,CD,NPR)
      IF(NPW.NE.0.AND.NPR.NE.0)WRITE(6,506)PW1
      CALL INPUT(NPW,1,IM,PW,NPR)
      IF(NPR.NE.0)WRITE(6,506)PREC1
      CALL INPUT(1,1,IM,PREC,NPR)
      IF(NPR.NE.0)WRITE(6,506)TEMP1
      CALL INPUT(1,1,IM,TEMP,NPR)
      IF(NMID.NE.0.AND.NPR.NE.0)WRITE(6,506)EMID1
      CALL INPUT(NMID,1,IM,EMID,NPR)
      IF(NMI.NE.0.AND.NPR.NE.0)WRITE(6,506)EMI1
      CALL INPUT(NMI,1,IM,EMI,NPR)
      IF(NTIF.NE.0.AND.NPR.NE.0)WRITE(6,506)TIF1
```

Figure G-4. Listing of program HYDRO with data input and program output.

```
      CALL INPUT(NTIF,1,IM,TIF,NPR)
      IF(NRES.NE.0.AND.NPR.NE.0)WRITE(6,506)RES1
      CALL INPUT(NRES,1,IM,RES,NPR)
      IF(NEXPO.NE.0.AND.NPR.NE.0)WRITE(6,506)EXPO1
      CALL INPUT(NEXPO,1,IM,EXPO,NPR)
      IF(NGFLO.NE.0.AND.NPR.NE.0)WRITE(6,506)GFLO1
      CALL INPUT(NGFLO,1,IM,GFLO,NPR)
      IF(NGWOF.NE.0.AND.NPR.NE.0) WRITE(6,506) GWOF1
      CALL INPUT(NGWOF,1,IM,GWOF,NPW)
C
C     INITIALIZATION OF ANNUAL COLUMN AND TOTALS FOR ALL ITEMS NOT
C     CALLED BY SUBROUTINE INPUT
C
   18 SSC(IMT)=0.
      STIF(IMT)=0.
      GWIN(IMT)=0.
      GWTS(IMT)=0.
      SINT(IMT)=0.
      SSW(IMT)=0.
      SMA(IMT)=0.
      DSC(IMT)=0.
      SMW(IMT)=0.
      DSW(IMT)=0.
      SGW(IMT)=0.
      DGW(IMT)=0.
      DCG(IMT)=0.
      DRES(IMT)=0.
      USW(IMT)=0.
      DWRZ(IMT)=0.
      PCL(IMT)=0.
      TSRZ(IMT)=0.
      SPCU(IMT)=0.
      EMIR(IMT)=0.
      SMS(IMT)=0.
      DEF(IMT)=0.
      ACU(IMT)=0.
      AGW(IMT)=0.
      RTFLO(IMT)=0.
      SWL(IMT)=0.
      PWL(IMT)=0.
      AWLCU(IMT)=0.
      SWLCU(IMT)=0.
      TAVE(IMT)=0.
      F(IMT)=0.
      SOF(IMT)=0.
      TOF(IMT)=0.
      GWRT(IMT)=0.
      SRTF(IMT)=0.
      PRES(IMT)=0.
      EVAP(IMT)=0.
      WEVAP(IMT)=0.
      WLSM(IMT)=0.
      WLAGW(IMT)=0.
      TGWA(IMT)=0.
      WLSFC(IMT)=0.
      DELGW(IMT)=0.
      IF(NC1)21,21,19
   19 DO 20 K=1,NC1
      PCUU(IMT,K)=0.
   20 PCU(IMT,K)=0.
   21 IF(NC2)24,24,22
   22 DO 23 K=1,NC2
      WLCUU(IMT,K)=0.
   23 WLCU(IMT,K)=0.
   24 CONTINUE
C
C     CALCULATE CHANGE IN RESERVOIR STORAGE.  RES(I) IS STORAGE AT END
C     OF PERIOD I.
C
      DRES(1)=RES(1)-RESF
      DO 16 I=2,IM
   16 DRES(I)=RES(I)-RES(I-1)
      RES(IMT)=RES(IM)
      DRES(IMT)=RES(IM)-RESF
C
C     BUDGET CALCULATIONS BEGIN HERE
C
      EKT=1.
      DO 60 I=1,IM
C
C     CALCULATE POTENTIAL CONSUMPTIVE USE
C
      TAVE(I)=CT+TEMP(I)
      F(I)=TAVE(I)*PDM(I)
      IF(NRC.NE.0)EKT=.0173*TAVE(I)-.314
      IF(EKT.LT..3)EKT=.3
      SPCU(I)=0.
      IF(NC1)29,29,27
   27 DO 28 K=1,NC1
      PCUU(I,K)=F(I)*EKT*AGSC(I,K)
      PCU(I,K)=PCUU(I,K)*AC1(K)/12.
   28 SPCU(I)=SPCU(I)+PCU(I,K)
   29 SWLCU(I)=0.
      IF(NC2)32,32,30
   30 DO 31 K=1,NC2
      WLCUU(I,K)=F(I)*EKT*PGSC(I,K)
      WLCU(I,K)=WLCUU(I,K)*AC2(K)/12.
   31 SWLCU(I)=SWLCU(I)+WLCU(I,K)
C
C     CALCULATE PRECIPITATION AND EVAPORATION FROM RESERVOIR
C
   32 EVAP(I)=0.
      WEVAP(I)=0.
      PRES(I)=0.
      IF(NRES.EQ.0) GO TO 205
      WEVAP(I)=F(I)*EKT*WGSC(I)
      EVAP(I)=WEVAP(I)*TARES/12.
      PRES(I)=PREC(I)*CPR*TARES/12.
C
C     CALCULATE SNOW STORAGE AND SNOW MELT
C
```

```
  205 PCL(I)=PREC(I)*CC*TAC/12.
      PWL(I)=PREC(I)*CW*TAWL/12.
      IF(TAVE(I).GT.TP) GO TO 301
      DSC(I)=PCL(I)
      DSW(I)=PWL(I)
      GO TO 302
  301 DSC(I)=0.
      DSW(I)=0.
  302 SSC(I+1)=SSC(I)+DSC(I)
      SSW(I+1)=SSW(I)+DSW(I)
      IF(TAVE(I).GT.TSM) GO TO 305
      SMA(I)=0.
      SMW(I)=0.
      GO TO 310
  305 SMA(I)=EMS*(TAVE(I)-TSM)*SSC(I+1)
      SMW(I)=EMS*(TAVE(I)-TSM)*SSW(I+1)
      IF(SMA(I).GT.SSC(I+1))SMA(I)=SSC(I+1)
      IF(SMW(I).GT.SSW(I+1))SMW(I)=SSW(I+1)
  310 SSC(I+1)=SSC(I+1)-SMA(I)
      SSW(I+1)=SSW(I+1)-SMW(I)
C
C     CALCULATE SURFACE UNMEASURED INFLOW AND GW INFLOW
C
      STIF(I)=TIF(I)*STFN(I)
      GWIN(I)=TIF(I)-STIF(I)
C
C     CALCULATE ROOT ZONE SUPPLY AND CROPLAND RETURN FLOW
C
      DWRZ(I)=CD(I)*EFCV*EFOF
      TSRZ(I)=DWRZ(I)+PCL(I)-DSC(I)+SMA(I)
      SMS(I)=TSRZ(I)-SPCU(I)
      RTFLO(I)=CD(I)-DWRZ(I)
      GWRT(I)=RTN(I)*RTFLO(I)
      SRTF(I)=RTFLO(I)-GWRT(I)
      IF(SMS(I))33,33,35
   33 IF(SMS(I)+ASMS(I))34,34,35
   34 ASMS(I+1)=0.
      AGW(I)=0.
      DEF(I)=SMS(I)+ASMS(I)
      ACU(I)=SPCU(I)+DEF(I)
      GO TO 45
   35 ASMS(I+1)=ASMS(I)+SMS(I)
      IF(ASMS(I+1)-SMC)38,38,40
   38 AGW(I)=0.
      GO TO 43
   40 AGW(I)=ASMS(I+1)-SMC
      ASMS(I+1)=SMC
   43 ACU(I)=SPCU(I)
      DEF(I)=0.
C
C     CALCULATE INTERFLOW GW STORAGE CHANGES, INTERFLOW TO SURFACE
C     AND INTERFLOW ADDITION TO GROUNDWATER
C
   45 GIN=AGW(I)+GWRT(I)+GWIN(I)
      EKGW2=EKGW+2.
      SINT(I)=0.
      IF(IG.EQ.0) GO TO 66
      DGW(I)=(TRI+TRI+STW(IG))*EKGW/EKGW2
      IF(DGW(I).GT.GWC) GO TO 62
      DGW(I)=GWC
      IF(TRI+STW(IG).LT.DGW(I)) DGW(I)=TRI+STW(IG)
   62 TRI=TRI+STW(IG)-DGW(I)
      IF(IG.EQ.1) GO TO 65
      DO 63 K=IG,2,-1
   63 STW(K)=STW(K-1)
   65 SGW(I+1)=SGW(I)+GIN-DGW(I)
      GO TO 67
   66 SGW(I+1)=((2.-EKGW)*SGW(I)+GIN+GIN)/EKGW2
      IF(SGW(I+1).LE.GWCAP) GO TO 46
      SGW(I+1)=GWCAP
      DGW(I)=(SGW(I)+GWCAP)*.5*EKGW
      SINT(I)=SGW(I)+GIN-DGW(I)-GWCAP
      GO TO 64
   46 DGW(I)=(SGW(I)+SGW(I+1))*.5*EKGW
   64 IF(DGW(I).GE.GWC) GO TO 67
      DGW(I)=GWC
      SGW(I+1)=SGW(I)+GIN-GWC
      IF(SGW(I+1).GE.0.) GO TO 67
      SGW(I+1)=0.
      DGW(I)=SGW(I)+GIN
      GO TO 68
   67 IF(SGW(I+1).LE.GWCAP) GO TO 68
      SINT(I)=SGW(I+1)-GWCAP
      SGW(I+1)=GWCAP
   68 STW(1)=GIN-SINT(I)
      WLAGW(I)=0.
      WLSFC(I)=0.
      IF(NC2.EQ.0) GO TO 253
C
C     CALCULATE INTERFLOW SUPPLY TO WETLAND AND INTERFLOW TO SURFACE
C     CALCULATE WETLAND ROOT ZONE STORAGE, CONSUMPTIVE USE, WETLAND
C     SURFACE RETURN FLOW AND GROUNDWATER ADDITION
C
      SWL(I)=SINT(I)*SWLN(I)
      SINT(I)=SINT(I)-SWL(I)
      TSWL(I)=SWL(I)+PWL(I)-DSW(I)+SMW(I)
      WLSM(I)= TSWL(I)-SWLCU(I)
      IF(WLSM(I)) 215,215,220
  215 IF(WLSM(I)+AWLSM(I))216,216,220
  216 AWLSM(I+1)=0.
      WLAGW(I)=0.
      WLDEF(I)=WLSM(I)+AWLSM(I)
      AWLCU(I)= SWLCU(I)+WLDEF(I)
      GO TO 250
  220 AWLSM(I+1)= AWLSM(I)+WLSM(I)
      IF(AWLSM(I+1)-WLSMC) 225,225,230
  225 WLAGW(I)=0.
      GO TO 235
  230 WLAGW(I)= AWLSM(I+1)-WLSMC
      AWLSM(I+1)= WLSMC
  235 AWLCU(I)= SWLCU(I)
      WLDEF(I)=0.
```

Figure G-4. Continued.

```
C
C     SEPARATE WLAGW INTO SURFACE AND GW COMPONENTS
C
  250 GWWL=(AWLSM(I)+AWLSM(I+1))*.5*WGWK
      WLSFC(I)=WLAGW(I)-GWWL
      IF(WLSFC(I))251,252,252
  251 WLSFC(I)=0.
      GO TO 253
  252 WLAGW(I)=GWWL
C
C     CALCULATE M AND I RETURN FLOW, TOTAL USEABLE WATER, SURFACE
C     OUTFLOW,TOTAL GW ADDITION, TOTAL OUTFLOW, DIFFERENCE BETWEEN
C     COMPUTED AND GAGED OUTFLOW, AND THE TWO ERROR TERMS AND GWTS
C
  253 GWTS(I)=SINT(I)+WLSFC(I)
      EMIR(I)=EMID(I)-EMI(I)
      USW(I)=RIF(I)+STIF(I)+PRES(I)+PW(I)-EVAP(I)+RES(I)-DRES(I)+SRTF(I)
     1+EMIR(I)+GWTS(I)+SIMP(I)
      SOF(I)=USW(I)-RES(I)-CD(I)-EXPO(I)-EMID(I)
      TGWA(I)=WLAGW(I)+DGW(I)
      TOF(I)=SOF(I)+TGWA(I)-PW(I)
      DCG(I)=SOF(I)-GFLO(I)
      ERR=ERR+DCG(I)*DCG(I)
      ERR1=ERR1+ABS(DCG(I))
C
C     CALCULATE ANNUAL VALUES FOR YEAR FOR VARIABLES NOT READ IN BY
C     SUBROUTINE INPUT
C
      IF(NRES.EQ.0) GO TO 260
      PRES(IMT)=PRES(IMT)+PRES(I)
      WEVAP(IMT)=WEVAP(IMT)+WEVAP(I)
      EVAP(IMT)= EVAP(IMT)+EVAP(I)
  260 PCL(IMT)=PCL(IMT)+PCL(I)
      STIF(IMT)=STIF(IMT)+STIF(I)
      GWIN(IMT)=GWIN(IMT)+GWIN(I)
      GWTS(IMT)=GWTS(IMT)+GWTS(I)
      SINT(IMT)=SINT(IMT)+SINT(I)
      SMS(IMT)=SMS(IMT)+SMS(I)
      TAVE(IMT)=TAVE(IMT)+TAVE(I)/ZIM
      F(IMT)=F(IMT)+F(I)
      DWRZ(IMT)=DWRZ(IMT)+DWRZ(I)
      GWRT(IMT)=GWRT(IMT)+GWRT(I)
      SRTF(IMT)=SRTF(IMT)+SRTF(I)
      TSRZ(IMT)=TSRZ(IMT)+TSRZ(I)
      RTFLO(IMT)=RTFLO(IMT)+RTFLO(I)
      DEF(IMT)=DEF(IMT)+DEF(I)
      SPCU(IMT)=SPCU(IMT)+SPCU(I)
      ACU(IMT)=ACU(IMT)+ACU(I)
      AGW(IMT)=AGW(IMT)+AGW(I)
      SWLCU(IMT)=SWLCU(IMT)+SWLCU(I)
      PWL(IMT)=PWL(IMT)+PWL(I)
      SOF(IMT)=SOF(IMT)+SOF(I)
      WLSFC(IMT)=WLSFC(IMT)+WLSFC(I)
      TOF(IMT)=TOF(IMT)+TOF(I)
      DSC(IMT)=DSC(IMT)+DSC(I)
      DSW(IMT)=DSW(IMT)+DSW(I)
      SMA(IMT)=SMA(IMT)+SMA(I)
      SMW(IMT)=SMW(IMT)+SMW(I)
      DGW(IMT)=DGW(IMT)+DGW(I)
      SWL(IMT)=SWL(IMT)+SWL(I)
      TSWL(IMT)=TSWL(IMT)+TSWL(I)
      TGWA(IMT)=TGWA(IMT)+TGWA(I)
      EMIR(IMT)=EMIR(IMT)+EMIR(I)
      USW(IMT)=USW(IMT)+USW(I)
      IF(NC1.EQ.0) GO TO 48
      DO 47 K=1,NC1
      PCUU(IMT,K)=PCUU(IMT,K)+PCUU(I,K)
   47 PCU(IMT,K)=PCU(IMT,K)+PCU(I,K)
   48 IF(NC2.EQ.0) GO TO 60
      DO 49 L=1,NC2
      WLCUU(IMT,L)=WLCUU(IMT,L)+WLCUU(I,L)
   49 WLCU(IMT,L)=WLCU(IMT,L)+WLCU(I,L)
      AWLCU(IMT)= AWLCU(IMT)+AWLCU(I)
      WLSM(IMT)=WLSM(IMT)+WLSM(I)
      WLAGW(IMT)=WLAGW(IMT)+WLAGW(I)
      WLDEF(IMT)=WLDEF(IMT)+WLDEF(I)
   60 CONTINUE
C
C     CALCULATE GW OUTFLOW AND CHANGE IN GW STORAGE FOR EACH MONTH
C
      IF(NGWOF.NE.0) GO TO 72
      GWOF(IMT)=TKGW*TOF(IMT)
      DGX=TGWA(IMT)
      IF(DGX.LE.0.) DGX=1.
      PKGW=GWOF(IMT)/DGX
   72 DO 61 I=1,IM
      IF(NGWOF.NE.0) GO TO 61
      GWOF(I)=TGWA(I)*PKGW
   61 DELGW(I)=TGWA(I)-PW(I)-GWOF(I)
C
C     CALCULATE ANNUAL VALUES FOR CHANGE IN GW STORAGE, DIFFERENCE
C     BETWN COMPUTED AND GAGED SURFACE OUTFLOW
C
      DELGW(IMT)=TGWA(IMT)-PW(IMT)-GWOF(IMT)
      DCG(IMT)=SOF(IMT)-GFLO(IMT)
C
C     OUTPUT OF MASS BALANCE WATER BUDGET
C
      IF(LTP.EQ.3) GO TO 889
      WRITE(6,1001) IT,NAME
 1001 FORMAT('1ITERATION'I3,25X20A4)
      GO TO (890,891,889),LTP
  889 WRITE(6,900)IT,IDSENS,NAME
  900 FORMAT('0ITERATION'I3,' ON 'A6,4X20A4)
  891 IF(ISENS.LE.0) GO TO 890
      GO TO(851,852,853,854,855,856,857,858,859,860,861,862,863,864,865,
     1866,867,868,869,870,871,872,873,874,875,876,841,842,877,878,879,
     2880),ISENS
  851 IF(IG.EQ.0)GO TO 890
      WRITE(6,901)IG,(SKW(I),I=1,IG),SKW(IG+1)
  901 FORMAT(1X'IG ='I3,' INTERFLOW GW COEF'13F8.3)
      GO TO 890
  852 WRITE(6,902)IDSENS,EFOF
  902 FORMAT(1XA6,' = 'F15.5,2F15.0)
      GO TO 890
  853 WRITE(6,902)IDSENS,GWCAP
      GO TO 890
  854 WRITE(6,902)IDSENS,CC
      GO TO 890
  855 WRITE(6,902)IDSENS,CW
      GO TO 890
  856 WRITE(6,902)IDSENS,CT
      GO TO 890
  857 WRITE(6,902)IDSENS,EXGW
      GO TO 890
  858 WRITE(6,902)IDSENS,EXS
      GO TO 890
  859 WRITE(6,902)IDSENS,TP
      GO TO 890
  860 WRITE(6,902)IDSENS,TSM
      GO TO 890
  861 WRITE(6,902)IDSENS,ASMS(1)
      GO TO 890
  862 WRITE(6,902)IDSENS,RZD,SMC
      GO TO 890
  863 WRITE(6,902)IDSENS,SMC1,SMC
      GO TO 890
  864 WRITE(6,902)IDSENS,SSO,SSC(1),SSW(1)
      GO TO 890
  865 WRITE(6,902)IDSENS,SGW(1)
      GO TO 890
  866 WRITE(6,902)IDSENS,GWC
      GO TO 890
  867 WRITE(6,902)IDSENS,TKGW
      GO TO 890
  868 WRITE(6,902)IDSENS,GWCAP
      GO TO 890
  869 WRITE(6,902)IDSENS,CPP
      GO TO 890
  870 WRITE(6,902)IDSENS,WGWK
      GO TO 890
  871 WRITE(6,902)IDSENS,AWLSM(1)
      GO TO 890
  872 WRITE(6,902)IDSENS,WLSMC
      GO TO 890
  873 WRITE(6,510)(RTK(I),I=1,IM)
      GO TO 890
  874 WRITE(6,902)IDSENS,WLSMC
      GO TO 890
  875 WRITE(6,517)(STFK(I),I=1,IM)
      GO TO 890
  876 WRITE(6,518)(SWLK(I),I=1,IM)
      GO TO 890
  841 WRITE(6,550)TIF1,(TIF(I),I=1,IMT)
      GO TO 890
  842 WRITE(6,550)GWOF1,(GWOF(I),I=1,IMT)
      GO TO 890
  877 WRITE(6,1010)PREC1,(PREC(I),I=1,IMT)
      GO TO 890
  878 WRITE(6,1010)TEMP1,(TAVE(I),I=1,IMT)
      GO TO 890
  879 WRITE(6,507)(PAC1(J),J=1,NC1)
      GO TO 890
  880 WRITE(6,505)(PAC2(J),J=1,NC2)
  890 WRITE(6,560)LYR,VAR1
  560 FORMAT(11H ITEM--YEAR,A5,11X,13(2X,A6))
      IF(LTP.EQ.3) GO TO 892
  550 FORMAT(1H ,5A5,12F8.2,F9.0)
      WRITE(6,550)RIF1,(RIF(I),I=1,IMT)
      IF(NSIMP.NE.0)WRITE(6,550)SIMP1,(SIMP(I),I=1,IMT)
      WRITE(6,550)TIF1,(TIF(I),I=1,IMT)
      WRITE(6,550)STIF1,(STIF(I),I=1,IMT)
      WRITE(6,550)GWIN1,(GWIN(I),I=1,IMT)
      IF(NRES.EQ.0) GO TO 125
      WRITE(6,550) RES1,(RES(I),I=1,IMT)
      WRITE(6,550) PRES1,(PRES(I),I=1,IMT)
      WRITE(6,550) EVAP1,(EVAP(I),I=1,IMT)
      WRITE(6,550)DRES1,(DRES(I),I=1,IMT)
  125 IF(NPW.NE.0)WRITE(6,550)PW1,(PW(I),I=1,IMT)
      IF(NC1.NE.0)WRITE(6,550)SRTF1,(SRTF(I),I=1,IMT)
      WRITE(6,550)GWTS1,(GWTS(I),I=1,IMT)
      IF(NMI.NE.0)WRITE(6,550)EMIR1,(EMIR(I),I=1,IMT)
      WRITE(6,550)USW1,(USW(I),I=1,IMT)
      IF(NEXPO.NE.0)WRITE(6,550)EXPO1,(EXPO(I),I=1,IMT)
      IF(NMI.EQ.0) GO TO 128
      WRITE(6,550)EMID1,(EMID(I),I=1,IMT)
      WRITE(6,550)EMI1,(EMI(I),I=1,IMT)
  128 IF(NC1.EQ.0) GO TO 127
      WRITE(6,550)CD1,(CD(I),I=1,IMT)
      WRITE(6,550)DWRZ1,(DWRZ(I),I=1,IMT)
      WRITE(6,550)RTFLO1,(RTFLO(I),I=1,IMT)
      WRITE(6,550)PCL1,(PCL(I),I=1,IMT)
      WRITE(6,550)DSC1,(DSC(I),I=1,IMT)
      WRITE(6,550)SSC1,(SSC(I),I=1,IMT)
      WRITE(6,550)SMA1,(SMA(I),I=1,IMT)
      WRITE(6,550)TSRZ1,(TSRZ(I),I=1,IMT)
      WRITE(6,550)SPCU1,(SPCU(I),I=1,IMT)
      WRITE(6,550)SMS1,(SMS(I),I=1,IMT)
      WRITE(6,550)ASMS1,(ASMS(I),I=1,IMT)
      WRITE(6,550)DEF1,(DEF(I),I=1,IMT)
      WRITE(6,550)ACU1,(ACU(I),I=1,IMT)
      WRITE(6,550)AGW1,(AGW(I),I=1,IMT)
      WRITE(6,550)GWRT1,(GWRT(I),I=1,IMT)
  127 WRITE(6,550)SGW1,(SGW(I),I=1,IMT)
      WRITE(6,550)SINT1,(SINT(I),I=1,IMT)
      IF(NC2.EQ.0) GO TO 126
      WRITE(6,550) SWL1,(SWL(I),I=1,IMT)
      WRITE(6,550)PWL1,(PWL(I),I=1,IMT)
      WRITE(6,550)DSW1,(DSW(I),I=1,IMT)
      WRITE(6,550)SSC1,(SSW(I),I=1,IMT)
      WRITE(6,550)SMW1,(SMW(I),I=1,IMT)
      WRITE(6,550)TSWL1,(TSWL(I),I=1,IMT)
      WRITE(6,550) SWLCU1,(SWLCU(I),I=1,IMT)
      WRITE(6,550) WLSM1,(WLSM(I),I=1,IMT;
      WRITE(6,550) AWLSM1,(AWLSM(I),I=1,IMT)
      WRITE(6,550) WLDEF1,(WLDEF(I),I=1,IMT)
```

Figure G-4. Continued.

```
      WRITE(6,550) AWLCU1,(AWLCU(I),I=1,IMT)
      WRITE(6,550)WLSFC1,(WLSFC(I),I=1,IMT)
      WRITE(6,550) WLAGW1,(WLAGW(I),I=1,IMT)
  126 WRITE(6,550)DGW1,(DGW(I),I=1,IMT)
      WRITE(6,550)TGWA1,(TGWA(I),I=1,IMT)
  892 WRITE(6,550) TOF1,(TOF(I),I=1,IMT)
      WRITE(6,550)GWOF1,(GWOF(I),I=1,IMT)
      WRITE(6,550)DELGW1,(DELGW(I),I=1,IMT)
      WRITE(6,550)SOF1,(SOF(I),I=1,IMT)
      IF(NGFLO.EQ.0)GO TO 129
      WRITE(6,550)GFLO1,(GFLO(I),I=1,IMT)
      WRITE(6,550)DCG1,(DCG(I),I=1,IMT)
      ERR=ERR+DCG(IMT)*DCG(IMT)
      ERR1=ERR1+ABS(DCG(IMT))
      WRITE(6,903)ERR,ERR1
  903 FORMAT(1X*SSQ DIF =*F16.0,5X*SUM OF ABSOLUTE DIFF =*F16.0)
  129 IF(IG.EQ.0) GO TO 80
      WRITE(6,516)(STW(I),I=1,IG),TR1,SGW(IMT)
  516 FORMAT(1X*FINAL INTERFLOW GW SUBDIV*13F8.0)
      DO 79 I=1,IG
   79 STW(I)=STW(I)/SGW(IMT)
      STW(IG+1)=TR1/SGW(IMT)
      WRITE(6,515)(STW(I),I=1,IG),STW(IG+1)
  515 FORMAT(1X*FINAL INTERFLOW GW COEF*2X13F8.3)
   80 IF(NCU.EQ.0) GO TO 87
C
C     OUTPUT OF CONSUMPTIVE USE DATA IF NCU NE 0
C
      WRITE(6,1005)
 1005 FORMAT(1H1,50X,28HCONSUMPTIVE USE CALCULATIONS)
      WRITE(6,1006)LYR,VAR1
 1006 FORMAT(7X4HYEAR,A5,11X,13(2X,A6))
 1010 FORMAT(1X5A5,12F8.2,F9.2)
 1011 FORMAT(1XI2,1XA6,15H UNIT USE (IN.),1X12F8.2,F9.2)
 1012 FORMAT(1XI2,1XA6,14H USE (ACRE-FT)2X12F8.0,F9.3)
 1013 FORMAT(1X18HAGRICULTURAL CROPS)
 1014 FORMAT(1X22HWET LAND PHREATOPHYTES)
      WRITE(6,1010)PREC1,(PREC(I),I=1,IMT)
      WRITE(6,1010)TEMP1,(TAVE(I),I=1,IMT)
      WRITE(6,1010)ACF,(F(I),I=1,IMT)
      IF(NC1.EQ.0) GO TO 160
      WRITE(6,1013)
      DO 150 K=1,NC1
      WRITE(6,1011)K,CROP(K),(PCUU(I,K),I=1,IMT)
  150 WRITE(6,1012)K,CROP(K),(PCU(I,K),I=1,IMT)
      WRITE(6,550)SPCU1,(SPCU(I),I=1,IMT)
      WRITE(6,550)ACU1,(ACU(I),I=1,IMT)
  160 IF(NC2.EQ.0) GO TO 171
      WRITE(6,1014)
      DO 170 K=1,NC2
      WRITE(6,1011)K,PHR(K),(WLCUU(I,K),I=1,IMT)
  170 WRITE(6,1012)K,PHR(K),(WLCU(I,K),I=1,IMT)
      WRITE(6,550)SWLCU1,(SWLCU(I),I=1,IMT)
      WRITE(6,550)AWLCU1,(AWLCU(I),I=1,IMT)
  171 IF(NRES.EQ.0) GO TO 87
      WRITE(6,1010)EVAP1,(WEVAP(I),I=1,IMT)
      WRITE(6,550)EVAP1,(EVAP(I),I=1,IMT)
   87 IF(NOD.EQ.0)GO TO 999
      DO 86 I=1,IMT
      QI(I)=RIF(I)*W(I)
      QS(I)=STIF(I)*W(I)
      QRES(I)=(PRES(I)-EVAP(I)-ORES(I))*W(I)
      QG(I)=GWTS(I)*W(I)
      QCD(I)=CD(I)*W(I)
      QEX(I)=EXPO(I)*W(I)
      QMID(I)=EMID(I)*W(I)
      QD(I)=(CD(I)+EXPO(I)+EMID(I))*W(I)
      QIR(I)=SRTF(I)*W(I)
      QEF(I)=EMIR(I)*W(I)
      QPW(I)=PW(I)*W(I)
      QTOF(I)=TOF(I)*W(I)
      QGWOF(I)=GWOF(I)*W(I)
      QDELGW(I)=DELGW(I)*W(I)
      QGFLO(I)=GFLO(I)*W(I)
      QDIFF(I)=DCG(I)*W(I)
   86 QO(I)=SOF(I)*W(I)
      WRITE(6,551)
  551 FORMAT(*0*30X*FLOW VALUES NEEDED FOR WATER QUALITY MODEL IN CFS*)
      IF(NCU.NE.0) GO TO 89
      WRITE(6,1006)LYR,VAR1
   89 WRITE(6,552)QI1,(QI(I),I=1,IMT)
  552 FORMAT(1XA5,2X12F9.2,F9.2)
      WRITE(6,552)QS1,(QS(I),I=1,IMT)
      IF(NOD.GT.1)GO TO 94
      WRITE(6,552)QPW1,(QPW(I),I=1,IMT)
      WRITE(6,552)QRES1,(QRES(I),I=1,IMT)
   94 WRITE(6,552)QG1,(QG(I),I=1,IMT)
      IF(NOD.GT.1)GO TO 95
      WRITE(6,552)QCD1,(QCD(I),I=1,IMT)
      WRITE(6,552)QEX1,(QEX(I),I=1,IMT)
      WRITE(6,552)QMID1,(QMID(I),I=1,IMT)
   95 WRITE(6,552)QD1,(QD(I),I=1,IMT)
      WRITE(6,552)QIR1,(QIR(I),I=1,IMT)
      WRITE(6,552)QEF1,(QEF(I),I=1,IMT)
      IF(NOD.GT.1)GO TO 96
      WRITE(6,552)QTOF1,(QTOF(I),I=1,IMT)
      WRITE(6,552)QGWOF1,(QGWOF(I),I=1,IMT)
      WRITE(6,552)QDGW1,(QDELGW(I),I=1,IMT)
   96 WRITE(6,552)QO1,(QO(I),I=1,IMT)
      IF(NGFLO.EQ.0)GO TO 999
      WRITE(6,552)QGFLO1,(QGFLO(I),I=1,IMT)
      WRITE(6,552)QDIFF1,(QDIFF(I),I=1,IMT)
  999 IF(IT.GE.ITN)GO TO 1
      LL=0
C
C     SELECTION OF ITERATION PARAMETERS
C
      NPRIT=NPRIT-1
      IT=IT+1
      GO TO(801,802,803,804,805,806,807,808,809,810,811,812,813,814,815
     1816,817,818,819,820,821,822,823,824,825,826,827,828,829,830,831,
     2832),ISENS
```

```
C     IG IS TIME INCREMENTS OF INTERFLOW STORAGE DELAY
  801 IG=IG+ENCRMT
      READ(5,104)(SKW(I),I=1,IG)
      GO TO 998
C     EFOF IS FARM IRRIGATION APPLICATION EFFICIENCY
  802 EFOF=EFOF+ENCRMT
      GO TO 998
C     GWCAP IS INTERFLOW STORAGE CAPACITY AND SGW(1) IS INITIAL
C     STORAGE IN INTERFLOW GROUNDWATER
  803 GWCAP=GWCAP+ENCRMT
      SGW(1)=GWCAP
      GO TO 998
C     CC IS COEFFICIENT TO ADJUST CROPLAND PRECIPITATION
  804 CC=CC+ENCRMT
      GO TO 998
C     CW IS ADJUSTING COEFFICIENT FOR WETLAND PRECIPITATION
  805 CW=CW+ENCRMT
      GO TO 998
C     CT IS COEFFICIENT TO ADJUST MODEL TEMPERATURE
  806 CT=CT+ENCRMT
      GO TO 998
C     EKGW IS DECAY CONSTANT FOR INTERFLOW STORAGE ADDED TO GW
  807 EKGW=EKGW+ENCRMT
      GO TO 998
C     EKS IS DECAY CONSTANT FOR SNOW MELT
  808 EKS = EKS + ENCRMT
      GO TO 998
C     TP IS THRESHOLD TEMPERATURE FOR SNOW STORAGE
  809 TP=TP+ENCRMT
      GO TO 998
C     TSM IS THRESHOLD TEMPERATURE FOR SNOW MELT
  810 TSM=TSM+ENCRMT
      GO TO 998
C     ASMS(1) IS INITIAL SOIL MOISTURE STORAGE IN CROPLAND
  811 ASMS(1)=ASMS(1)+ENCRMT
      GO TO 998
C     RZD IS ROOT ZONE DEPTH IN FEET
  812 RZD=RZD+ENCRMT
      SMC=RZD*SMC1*TAC/12.
      GO TO 998
C     SMC1 IS WATER HOLDING CAPACITY OF ROOT ZONE IN INCHES/FT
  813 SMC1=SMC1+ENCRMT
      SMC=RZD*SMC1*TAC/12.
      GO TO 998
C     SSO IS INITIAL SNOW STORAGE
  814 SSO=SSO+ENCRMT
      SSC(1)=SSO*TAC/12.
      SSW(1)=SSO*TAWL/12.
      GO TO 998
C     SGW(1) IS INITIAL INTERFLOW STORAGE
  815 SGW(1)=SGW(1)+ENCRMT
      GO TO 998
C     GWC IS MINIMUM GW DISCHARGE FROM INTERFLOW STORAGE
  816 GWC=GWC+ENCRMT
      GO TO 998
C     TKGW IS PROPORTION OF ANNUAL OUTFLOW THAT IS UNGAGED AND ASSUMED
C     TO BE GROUNDWATER OUTFLOW
  817 TKGW=TKGW+ENCRMT
      GO TO 998
C     GWCAP IS CAPACITY OF INTERFLOW STORAGE
  818 GWCAP=GWCAP+ENCRMT
      GO TO 998
C     CPR IS ADJUSTING COEFFICIENT FOR RESERVOIR PRECIPITATION
  819 CPR=CPR+ENCRMT
      GO TO 998
C     WGWK IS DECAY CONSTANT FOR WETLAND SOIL MOISTURE ADDED TO GW
  820 WGWK=WGWK+ENCRMT
      GO TO 998
C     AWLSM(1) IS INITIAL WETLAND SOIL MOISTURE STORAGE
  821 AWLSM(1)=AWLSM(1)+ENCRMT
      GO TO 998
C     WLSMC IS WETLAND SOIL MOISTURE CAPACITY
  822 WLSMC=WLSMC+ENCRMT
      GO TO 998
C     RTK ARE GROUNDWATER RETURN FLOW COEFFICIENTS FOR CROP LAND
  823 READ(5,104)(RTK(I),I=1,IM)
      GO TO 998
C     WLSMC IS WETLAND SOIL MOISTURE CAPACITY AND
C     AWLSM(1) IS INITIAL WETLAND SOIL MOISTURE STORAGE
  824 WLSMC=WLSMC+ENCRMT
      AWLSM(1)=WLSMC
      GO TO 998
C     STFK ARE SURFACE UNMEASURED INFLOW COEFFICIENTS
  825 READ(5,104)(STFK(I),I=1,IM)
      GO TO 998
C     SWLK ARE INTERFLOW SUPPLY TO WETLAND COEFFICIENTS
  826 READ(5,104)(SWLK(I),I=1,IM)
      GO TO 998
C     TIF IS UNMEASURED SURFACE INFLOW
  827 CMULT=CMULT+ENCRMT
      DO 843 I=1,IMT
  843 TIF(I)=TIF(I)*CMULT
      GO TO 998
C     GWOF IS GROUNDWATER OUTFLOW
  828 CMULT=CMULT+ENCRMT
      DO 844 I=1,IMT
  844 GWOF(I)=GWOF(I)*CMULT
      GO TO 998
C     PREC IS INPUT PRECIPITATION
  829 PREC(IMT)=0.
      READ(5,905)(PREC(I),I=1,IM)
  905 FORMAT(14X13F5.2)
      DO 845 I=1,IM
  845 PREC(IMT)=PREC(IMT)+PREC(I)
      GO TO 998
C     TEMP IS INPUT TEMPERATURE
  830 TEMP(IMT)=0.
      READ(5,906)(TEMP(I),I=1,IM)
  906 FORMAT(14X13F5.1)
      DO 846 I=1,IM
  846 TEMP(IMT)=TEMP(IMT)+TEMP(I)
      TEMP(IMT)=TEMP(IMT)/12.
```

Figure G-4. Continued.

```
      GO TO 998
C     PAC1 ARE PROPORTION OF CROPS AND SHOULD SUM TO 1
  831 READ(5,106)(PAC1(J),J=1,NC1)
      DO 847 J=1,NC1
  847 AC1(J)=TAC*PAC1(J)
      GO TO 998
C     PAC2 ARE PROPORTION OF WETLAND PHREATOPHYTES AND SHOULD SUM TO 1
  832 READ(5,106)(PAC2(J),J=1,NC2)
      DO 848 J=1,NC2
  848 AC2(J)=TAWL*PAC2(J)
      GO TO 998
      END
@I FOR INPUT,INPUT
      SUBROUTINE INPUT(N,NYR,IM,Q,NPR)
      COMMON LYR
      DIMENSION Q(13),F(13),FMT(14)
      IF(N.NE.0)READ(5,100)FMT
  100 FORMAT(13A6,A2)
      IMT=IM+1
      K=1
      IF(N-1)5,10,15
    5 DO 7 I=1,IMT
    7 Q(I)=0.
      GO TO 30
   10 L=1
      GO TO 16
   15 L=2
   16 READ(5,FMT)ID,(Q(I),I=1,IM)
      Q(IMT)=0.
      DO 17 I=1,IM
   17 Q(IMT)=Q(IMT)+Q(I)
      IF(NPR.NE.0)WRITE(6          ,LYR,(Q(I),I=1,IMT)
  101 FORMAT(1XI3,1XA6,1X          .0)
      GO TO (30,20),L
   20 DO 25 K=2,N
      READ(5,FMT)ID,(F(I),I    IM)
      F(IMT)=0.
      DO 21 I=1,IM
   21 F(IMT)=F(IMT)+F(I)
      IF(NPR.NE.0)WRITE(6,101)K,ID,LYR,(F(I),I=1,IMT)
      DO 25 I=1,IMT
   25 Q(I)=Q(I)+F(I)
      IF(NPR.NE.0)WRITE(6,102) LYR,(Q(I),I=1,IMT)
  102 FORMAT(1XA6,1X6HTOTALS,12X13F8.0)
   30 RETURN
      END
```

SAMPLE PROBLEM -- CARD SET-UP

```
  BN XQT HYDRO
  MEASURED INFLOW          IUNMEASURED INFLOW        I  RESERVOIR STORAGE
  CHANGE IN RES STORAGE   0  USEABLE SURFACE WATER     CROPLAND DIVERSIONS
    AMOUNT TO ROOT ZONE        PUMPED WATER            GROUNDWATER INFLOW
  CROPLAND PRECIPITATION  I  ROOT ZONE SUPPLY          RZ SUPPLY-P.C.U.
  ACCUM SOIL MOISTURE   I-0  CROPLAND P.C.U.           CONS. USE DEFICIT
  ACTUAL CROPLAND C.U.     0INPUT PRECIPITATION        CROPLAND RETURN FLOW
  M AND I NET USE          0  INTERFLOW SUPPLY TO WL WETLAND PRECIPITATION   I
    POTENTIAL WETLAND CU   EXPORTS                  0  SURFACE OUTFLOW
  AVERAGE TEMPERATURE      BLANEY-CRIDDLE 'F'          CHANGE IN GW STORAGE
    ACCUM SNOW STORAGE       SNOW MELT             ISNOW STORAGE ADDED       0
   INTERFLOW ADDED        ACCUM INTERFLOW       I-0  INTERFLOW TO GW
 OUTFLOW + CHANGE IN GW  0  GAGED SURFACE OUTFLOW     DIFFERENCE (COMP-GAGED)
   GW OUTFLOW               GW RETURN FLOW            SURFACE RETURN FLOW
 SNOW STORAGE ADDED      0SNOW MELT                I  TOTAL GW ADDED
 RESERVOIR PRECIPITATION IRESERVOIR EVAPORATION   0  TSWL-WL PCU
 ACTUAL WETLAND C.U.     0ACCUM WL SOIL MOIST   I-0  WETLAND DEFICIT
   WETLAND ADDITION TO GW   TOTAL SUPPLY TO WL     MEASURED IMPORTS         I
   M AND I DIVERSION          M AND I RETURN FLOW     WETLAND SURFACE OUTFLOW
   UNMEASURED SURFACE IN    GROUNDWATER TO SURFACE   INTERFLOW TO SURFACE
   OCT   NOV   DEC   JAN   FEB   MAR   APR   MAY   JUN   JUL   AUG   SEP ANNUAL
   1967 DATA  10-1060  LITTLE BEAR RIVER NEAR PARADISE, UTAH
 LBR-2  112 8 4 1 1 1 1 0 1 1 1 0 1 1 1 1 01 50 50 1000 1000 1000 375 100 350 240
 LBR-2      3683    1700     1306  1300  400   200    0     1300      200   100    1300
 LBR-2    2 1200   350          193        1700        1700
 LBR-2 RF COEF  1000 1000 1000 1000 1000 1000 1000  880  880  859  922  897
 LBR-2 STFK      102  144  154  161  173  479  647  631  844  659  522  684
 LBR-2 SWLK     1000 1000 1000 1000 1000 1000 1000 1000 1000 1000 1000 1000
 LBR-2 PDH       774  665  642  660  668  828  896 1037 1118 1077  967  862
 LBR-2 AC1    297   188   46   253   33   14   23   146
 LBR-2    ALFALF   89   80   65   64   73   87   99  115  118  109  104   98
 LBR-2    PASTRE   80   74   58   55   65   91   86  117   99   93   91   87
 LBR-2    HAY      85   77   62   60   72   83   96  119  108  121   98   92
 LBR-2    GRAIN    22   29   29   29   29   28   74  118  127   73   40   19
 LBR-2    CORN     99   28   29   29   28   28   22   60   73   93  106  109
 LBR-2    BEETS   102   28   29   29   29   28   22   58   75   96  108  111
 LBR-2    TRUCK    22   29   29   29   29   29   22   56   72   83   76   19
 LBR-2    UR-IDL   35   30   25   25   28   30   33   38   39   39   39   39
 LBR-2 AC2     91   481   293   135
 LBR-2    VRDNPH  154  147  131  123  150  167  171  169  164  158  155  154
 LBR-2    DNSPHY  137  128  112  101  130  149  156  155  151  144  141  138
 LBR-2    MEDPHY  119  110   93   80  110  137  141  141  138  130  136  122
 LBR-2    LTPHRY   93   91   77   67  105  120  120  110  108   98   97   95
 LBR-2    WATER   137  128  112  101  130  149  156  155  151  144  141  138
 LBR-2        1967
 (A6,8X12F5.0)
  RIF        1967 1753 1736 1924 1933 1811 4800102802593014660 5280 3098 2424 75629
 (A6,8X12F5.0)
  CD         1967  300                                         3516 4980 4825 3156
 (A6,8X12F4.2)
 LOGUSU      1967  43 131 171 163  74 330 446 195 356  77  11  12
 (A6,8X12F4.1)
 LOGUSU      1967 483 407 228 286 319 385 422 537 607 781 739 619
 (6XA4,4X12F5.0)
 WTRFRMWDIV1967 1537 1488 1537 1537 1388 1537 1785 1864 1784 1865 1845 1785
 (6XA4,4X12F5.0)
 WTRFRM MI 1967 -307 -298 -307 -307 -278 -307 -298 -307 -298 -307 -307 -298
 (6XA4,4X12F5.0)
 LBR-2 TIF 1967 1904 2075 2178 2059 1847 1660 2817 4330 4750 2413 1812 2365
 (A6,8X,12F5.0)
 PORRES          1573 2070 2628 3210 3618 5289 97451246012840 9978 5852 3390
 (A6,8X12F5.0)
 HYRM C      1967                                         2368 3316 2143 1368
 (A6,8X12F5.0)
 101060      1967 2250 2480 2720 2570 2533 5350 89202633016340 3620 3912 3410
 (6XA4,4X12F5.0)
 LBR-2 GWOF1967 1000 1000 1000 1000 1000 1000 1000 1000 1000 1000 1000 1000
```

GROUP 1 CARDS
OUTPUT LABELS

GROUP 2 CARDS
PARAMETER INITIALIZATION

GROUP 3 CARDS
INPUT DATA

Figure G-4. Continued.

```
                                                         OUTPUT FROM SAMPLE PROBLEM

ITERATION  1                          1967 DATA  10-1060  LITTLE BEAR RIVER NEAR PARADISE, UTAH
ITEM--YEAR 1967                 OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP    ANNUAL
MEASURED INFLOW           I   1753.   1736.   1924.   1933.   1811.   4800.  10280.  25930.  14660.   5280.   3098.   2424.   75629.
UNMEASURED INFLOW         I   1904.   2335.   2378.   2059.   1840.   1660.   2817.   4330.   4750.   2413.   1812.   2365.   30363.
  UNMEASURED SURFACE IN        194.    291.    366.    331.    318.    780.   1259.   1466.   4009.   1180.    946.   1618.   13161.
  GROUNDWATER INFLOW          1710.   1742.   2012.   1728.   1522.    880.   1558.   2864.    741.   1233.    866.    747.   17202.
  RESERVOIR STORAGE           1573.   3070.   2624.   3210.   3818.   5239.   9745.  12840.  12840.   9908.   5850.   3390.    3390.
RESERVOIR PRECIPITATION I        8.     25.     33.     31.     14.     64.     86.     38.     69.      7.      2.      2.     380.
RESERVOIR EVAPORATION     O     43.     22.      8.      9.     13.     27.     39.     83.    110.    167.    155.     95.     772.
CHANGE IN RES STORAGE     O    267.    497.    558.    582.    608.   1421.   4506.   3095.      0.  -2932.  -4058.  -2460.    2084.
  SURFACE RETURN FLOW            0.      0.      0.      0.      0.      0.      0.      0.    316.    528.    262.    244.    1370.
  GROUNDWATER TO SURFACE       561.    666.    865.    789.    613.    849.   1784.    969.   1718.   2040.   1853.   1027.   13734.
  M AND I RETURN FLOW         1844.   1786.   1844.   1844.   1666.   1844.   2093.   2152.   2383.   2152.   2152.   2083.   23533.
  USEABLE SURFACE WATER       5624.   6398.   7098.   7547.   7619.  12128.  20692.  40617.  35545.  23860.  18085.  13153.  190063.
EXPORTS                   O      0.      0.      0.      0.      0.      0.      0.      0.   2368.   3316.   2143.   1349.    9176.
  M AND I DIVERSION           1537.   1488.   1537.   1537.   1388.   1537.   1785.   1845.   1785.   1845.   1845.   1785.   19914.
M AND I NET USE           O   -307.   -298.   -307.   -307.   -278.   -307.   -298.   -307.   -298.   -307.   -307.   -298.   -3619.
  CROPLAND DIVERSIONS          300.      0.      0.      0.      0.      0.      0.      0.   3516.   4990.   4823.   3156.   16785.
  AMOUNT TO ROOT ZONE           75.      0.      0.      0.      0.      0.      0.      0.    879.   1247.   1206.    789.    4196.
  CROPLAND RETURN FLOW         225.      0.      0.      0.      0.      0.      0.      0.   2637.   3742.   3617.   2367.   12589.
CROPLAND PRECIPITATION    I    132.    402.    525.    500.    227.   1013.   1369.    598.   1093.    114.     34.     37.    6043.
SNOW STORAGE ADDED        O      0.      0.    525.    500.    227.      0.      0.      0.      0.      0.      0.      0.    1252.
  ACCUM SNOW STORAGE             0.      0.      0.    525.    554.    164.      0.      0.      0.      0.      0.      0.       0.
  SNOW MELT               I      0.      0.      0.    472.    617.    164.      0.      0.      0.      0.      0.      0.    1252.
  ROOT ZONE SUPPLY             207.    402.      0.    472.    617.   1177.   1369.    598.   1972.   1361.   1240.    826.   10239.
  CROPLAND P.C.U.              367.    178.     62.     78.     99.    201.    362.    999.   1423.   1880.   1580.    860.    8087.
  RZ SUPPLY-P.C.U.            -160.    224.    -62.    393.    518.    976.   1007.   -400.    549.   -519.   -340.    -34.    2152.
ACCUM SOIL MOISTURE     I-O   1300.   1187.   1364.   1302.   1695.   2213.   2455.   2455.   2055.   2455.   1937.   1596.    1562.
  CONS. USE DEFICIT              0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.       0.
ACTUAL CROPLAND C.U.      O    367.    178.     62.     78.     99.    201.    362.    999.   1423.   1880.   1580.    860.    8087.
  INTERFLOW ADDED                0.      0.      0.      0.      0.    734.   1007.      0.    149.      0.      0.      0.    1890.
  GW RETURN FLOW               225.      0.      0.      0.      0.      0.      0.      0.   2321.   3215.   3335.   2123.   11219.
ACCUM INTERFLOW         I-O   1300.   1300.   1300.   1300.   1300.   1300.   1300.   1300.   1300.   1300.   1300.   1300.    1300.
  INTERFLOW TO SURFACE           0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.       0.
  INTERFLOW SUPPLY TO WL      1447.   1258.   1576.   1240.   1034.   1126.   2077.   1976.   2723.   3960.   3714.   2383.   20460.
WETLAND PRECIPITATION     I     61.    186.    242.    231.    105.    467.    632.    276.    504.     52.     16.     17.    2789.
SNOW STORAGE ADDED        O      0.      0.    242.    231.    105.      0.      0.      0.      0.      0.      0.      0.     578.
  ACCUM SNOW STORAGE             0.      0.      0.    242.    256.     76.      0.      0.      0.      0.      0.      0.       0.
SNOW MELT                 I      0.      0.      0.    218.    285.     76.      0.      0.      0.      0.      0.      0.     578.
  TOTAL SUPPLY TO WL          1508.   1440.   1524.   1458.   1319.   1669.   2709.   2253.   3227.   4013.   3729.   2400.   27249.
  POTENTIAL WETLAND CU         352.    179.     64.     74.    111.    225.    330.    688.    914.   1378.   1282.    778.    6375.
  TSWL-WL PCU                 1156.   1261.   1460.   1384.   1208.   1444.   2379.   1564.   2313.   2635.   2448.   1622.   20874.
ACCUM WL SOIL MOIST     I-O   1700.   1700.   1700.   1700.   1700.   1700.   1700.   1700.   1700.   1700.   1700.   1700.    1700.
  WETLAND DEFICIT                0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.       0.
ACTUAL WETLAND C.U.       O    352.    179.     64.     74.    111.    225.    330.    688.    914.   1378.   1282.    778.    6375.
  WETLAND SURFACE OUTFLOW      561.    566.    865.    789.    613.    849.   1784.    969.   1718.   2040.   1853.   1027.   13734.
  WETLAND ADDITION TO GW       595.    595.    595.    595.    595.    595.    595.    595.    595.    595.    595.    595.    7140.
  INTERFLOW TO GW              487.    487.    487.    487.    487.    487.    487.    487.    487.    487.    487.    487.    5850.
  TOTAL GW ADDED              1082.   1082.   1082.   1082.   1082.   1082.   1082.   1082.   1082.   1082.   1082.   1082.   12990.
OUTFLOW + CHANGE IN GW #      3297.   3582.   4012.   3843.   3496.   6435.  10244.  27015.  16158.   4883.   4507.   4556.   92067.
  GW OUTFLOW                  1000.   1000.   1000.   1000.   1000.   1000.   1000.   1000.   1000.   1000.   1000.   1000.   12000.
  CHANGE IN GW STORAGE          82.     82.     82.     82.     82.     82.     82.     82.     82.     82.     82.     82.     990.
  SURFACE OUTFLOW             2214.   2500.   2929.   2800.   2413.   5352.   9162.  25932.  15076.   3801.   3424.   3473.   79077.
  GAGED SURFACE OUTFLOW       2250.   2480.   2720.   2570.   2530.   5350.   8920.  26300.  16340.   3600.   3910.   3410.   80380.
  DIFFERENCE (COMP-GAGED)      -36.     20.    209.    230.   -117.      2.    242.   -368.  -1264.    201.   -486.     63.   -1303.
SSQ DIF =        1483505.     SUM OF ABSOLUTE DIFF =          4542.


                                                      CONSUMPTIVE USE CALCULATIONS
      YEAR 1967                 OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP    ANNUAL
INPUT PRECIPITATION             .43    1.31    1.71    1.63     .74    3.30    4.46    1.95    3.56     .37     .11     .12    19.69
AVERAGE TEMPERATURE           48.10   43.70   22.80   28.60   31.90   38.50   47.20   53.70   69.70   73.10   73.90   63.90    48.19
BLANEY-CRIDDLE "F"             3.74    2.71    1.46    1.89    2.13    3.19    3.78    5.41    6.18    7.58    7.11    5.38    50.55
AGRICULTURAL CROPS
 1 ALFALF UNIT USE (IN.)       1.74     .44     .29     .36     .47     .98    1.56    3.87    5.41    7.85    7.13    4.17    34.62
 1 ALFALF USE (ACRE-FT)        158.     77.     26.     33.     43.     89.    142.    349.    493.    716.    650.    380.    3156.
 2 PASTRE UNIT USE (IN.)       1.56     .74     .25     .31     .42     .91    1.35    3.39    4.50    6.70    6.24    3.70    30.13
 2 PASTRE USE (ACRE-FT)         90.     45.     15.     18.     24.     52.     78.    196.    260.    387.    360.    214.    1739.
 3 HAY    UNIT USE (IN.)       1.66     .81     .27     .34     .45     .93    1.48    3.63    4.96    7.28    6.72    3.92    32.44
 3 HAY    USE (ACRE-FT)         23.     11.      4.      5.      6.     13.     21.     51.     70.    103.     95.     55.     458.
 4 GRAIN  UNIT USE (IN.)        .43     .31     .13     .16     .19     .31    1.16    3.92    5.78    5.26    2.74     .81    21.20
 4 GRAIN  USE (ACRE-FT)         33.     24.     10.     13.     14.     24.     90.    305.    449.    408.    213.     63.    1646.
 5 CORN   UNIT USE (IN.)       1.93     .31     .13     .16     .19     .31     .35    2.00    3.32    6.70    7.27    4.64    27.30
 5 CORN   USE (ACRE-FT)         20.      3.      1.      2.      2.      3.      4.     20.     34.     68.     74.     47.     277.
 6 BEETS  UNIT USE (IN.)       1.99     .31     .13     .16     .19     .31     .35    1.93    3.41    6.92    7.41    4.73    27.82
 6 BEETS  USE (ACRE-FT)          4.      1.      0.      0.      0.      1.      1.      8.     15.     30.     32.     20.     120.
 7 TRUCK  UNIT USE (IN.)        .43     .31     .13     .16     .19     .31     .35    1.86    3.28    5.98    5.21     .81    19.01
 7 TRUCK  USE (ACRE-FT)          3.      2.      0.      1.      1.      2.      2.     13.     23.     42.     37.      6.     134.
 8 UR-IDL UNIT USE (IN.)        .68     .32     .11     .14     .16     .34     .52    1.26    1.77    2.81    2.67    1.66    12.45
 8 UR-IDL USE (ACRE-FT)         31.     14.      5.      6.      7.     15.     23.     57.     79.    126.    120.     74.     558.
  CROPLAND P.C.U.              367.    178.     62.     78.     99.    201.    362.    999.   1423.   1880.   1580.    860.    8087.
ACTUAL CROPLAND C.U.      O    367.    178.     62.     78.     99.    201.    362.    999.   1423.   1880.   1580.    860.    8087.
WET LAND PHREATOPHYTES
 1 VRONPH UNIT USE (IN.)       3.90    1.55     .58     .70     .96    1.87    2.69    4.62    7.46   11.39   10.63    6.56    53.00
 1 VRONPH USE (ACRE-FT)         34.     20.      7.      9.     12.     24.     35.     72.     96.    147.    137.     85.     683.
 2 ONSPHY UNIT USE (IN.)       2.67    1.35     .49     .57     .83    1.67    2.45    5.15    6.87   10.38    9.67    5.88    47.99
 2 ONSPHY USE (ACRE-FT)        142.     92.     34.     39.     57.    114.    167.    351.    468.    707.    659.    400.    3270.
 3 MEDPHY UNIT USE (IN.)       2.32    1.16     .41     .45     .70    1.48    2.22    4.69    6.28    9.37    8.64    5.20    42.92
 3 MEDPHY USE (ACRE-FT)         96.     48.     17.     19.     29.     61.     92.    195.    261.    389.    359.    216.    1781.
 4 LTPHRY UNIT USE (IN.)       1.81     .96     .34     .38     .67    1.35    1.89    3.66    4.69    7.06    6.65    4.05    33.50
 4 LTPHRY USE (ACRE-FT)         35.     18.      6.      7.     13.     26.     36.     73.     90.    135.    127.     77.     641.
  POTENTIAL WETLAND CU         352.    179.     64.     74.    111.    225.    330.    688.    914.   1378.   1282.    778.    6375.
ACTUAL WETLAND C.U.       O    352.    179.     64.     74.    111.    225.    330.    688.    914.   1378.   1282.    778.    6375.
RESERVOIR EVAPORATION     O    2.67    1.35     .49     .57     .83    1.67    2.45    5.15    6.87   10.38    9.67    5.88    47.99
RESERVOIR EVAPORATION     O     43.     22.      8.      9.     13.     27.     39.     83.    110.    167.    155.     95.     772.

                                FLOW VALUES NEEDED FOR WATER QUALITY MODEL IN CFS
QI                            28.51   29.17   31.29   31.44   32.61   78.06  172.76  421.71  246.37   45.87   50.38   40.74   104.46
QS                             3.16    4.92    5.96    5.39    5.73   12.69   21.16   30.35   67.37   19.19   15.38   27.19    18.18
QGI                            9.13   11.20   14.07   12.83   11.03   13.81   29.98   15.76   28.87   33.18   30.13   17.26    18.97
QD                            24.88   25.01   25.00   25.00   24.99   25.00   30.00   30.01  128.88  165.09  143.30  105.71    63.37
QIP                             .00     .00     .00     .00     .00     .00     .00     .00    5.32    8.58    4.59    4.10     1.89
QEF                           29.99   30.01   29.99   29.99   30.00   29.99   35.01   35.00   35.01   35.00   35.00   35.01    32.51
QO                            36.01   47.71   47.64   45.54   43.45   87.04  153.97  421.75  253.35   61.82   55.69   58.37   109.23
QGFLO                         36.59   41.68   46.24   41.80   45.56   87.01  149.91  427.73  274.60   58.55   63.59   57.31   111.03
QDIFF                          -.59     .34    1.40    3.75   -2.11     .03    4.06   -5.98  -21.25    3.27   -7.90    1.06    -1.80
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Figure G-4. Continued.

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@ RUN USU,XXXXXX,1,100,,12  LEON HUBER
@ DPR
@I FOR BUDGET,BUDGET
C C    HYDROLOGIC MASS BALANCE MODEL PROGRAM
      COMMON LYR(35)
      INTEGER NAME(20)
      DIMENSION POH(12),AC1(10),RIF(13,32),F(13,32),CD(13,32),PW(13,32),
     1PREC(13,32),PCL(13,32),DWRZ(13,32),GWOF(13,32),TSRZ(13,32),
     2TEMP(13,32),AGSC(12,13),TAVE(13,32),PCUU(13,32,10),PCU(13,32,10),
     3PGSC(12, 9),AC2( 9),WLCU(13,32, 9),WLCUU(13,32, 9),PWL(13,32),
     4SPCU(13,32),SWLCU(13,32),SMS(13,32),ASMS(13,32),DEF(13,32),
     5ACU(13,32),AGW(13,32),EMI(13,32),TIF(13,32),SWL(13,32),SOF(13,32),
     6SGW(13,32),DGW(13,32),RTFLO(13,32),RES(13,32),EXPO(13,32),
     7TOF(13,32),GWRT(13,32),SRTF(13,32),STW(12),SKW(13),GWIN(13,32)
      DIMENSION PHP( 9),CROP(13),DRES(13,32),USW(13,32),GFLO(13,32),
     1DCG(13,32),SSC(13,32),SSW(13,32),SMA(13,32),SMW(13,32),DSC(13,32),
     2DSW(13,32),RTK(12),GWTS(13,32),AWLCU(13,32),PRES(13,32),STFK(12),
     3EVAP(13,32),WGSC(12),WLSM(13,32),AWLSM(13,32),WLAGW(13,32),
     4WLDEF(13,32),TSWL(13,32),SWLK(12),TGWA(13,32),EMID(13,32),
     5EMIR(13,32),WEVAP(13,32),EMID1(5),EMIR1(5),W(13),OI(13),OS(13),
     6OGI(13),OD(13),OIP(13),OEF(13),OO(13),ORES(13),OPW(13),ERR(32),
     7SINT(13,32),WLSFC(13,32),DELGW(13,32),SINT1(5),STIF(13,32),
     8OTOF(13),OGWOF(13),ODELGW(13),OGFLO(13),ODIFF(13),STIF1(5)
      DIMENSIONRIF1(5),TIF1(5),RES1(5),DRES1(5),USW1(5),CD1(5),PW1(5),
     1DWRZ1(5),GWOF1(5),PCL1(5),TSRZ1(5),SMS1(5),ASMS1(5),SPCU1(5),
     2DEF1(5),ACU1(5),AGW1(5),RTFLO1(5),EMI1(5),SWL1(5),PWL1(5),SSC1(5),
     3SWLCU1(5),EXPO1(5),TEMP1(5),RCF(5),OGW1(5),SOF1(5),SIMP(13,32),
     4PREC1(5),GFLO1(5),DCG1(5),SMA1(5),DSC1(5),SGW1(5),TOF1(5),
     5GWRT1(5),SRTF1(5),SMW1(5),DSW1(5),VAR1(13),GWIN1(5),GWTS1(5),
     6AWLCU1(5),PRES1(5),EVAP1(5),WLSM1(5),AWLSM1(5),WLDEF1(5),SIMP1(5),
     7WLAGW1(5),TSWL1(5),TGWA1(5),WLSFC1(5),DELGW1(5),PAC1(13),PAC2(9)
      DATA OI1,OS1,OGI1,OD1,OIP1,OEF1,OO1,ORES1,OPW1,OTOF1,OGWOF1,
     1ODGW1,OGFLO1,ODIFF1/2HOI,2HOS,3HOGI,2HOD,3HOIP,3HOEF,2HOO,4HORES,
     23HOPW,4HOTOF,5HOGWOF,4HODGW,5HOGFLO,5HODIFF/
C
C     READ LABELS FOR BUDGET OUTPUT
      READ(5,500)  RIF1,TIF1,RES1
      READ(5,500)  DRES1,USW1,CD1
      READ(5,500)  DWRZ1, PW1,GWIN1
      READ(5,500)  PCL1, TSRZ1, SMS1
      READ(5,500)  ASMS1, SPCU1, DEF1
      READ(5,500) ACU1,PREC1,RTFLO1
      READ(5,500)  EMI1, SWL1, PWL1
      READ(5,500) SWLCU1,EXPO1,SOF1
      READ(5,500)TEMP1,RCF,DELGW1
      READ(5,500) SSC1,SMA1,DSC1
      READ(5,500) AGW1,SGW1,DGW1
      READ(5,500) TOF1,GFLO1,DCG1
      READ(5,500) GWOF1,GWRT1,SRTF1
      READ(5,500) DSW1,SMW1,TGWA1
      READ(5,500) PRES1,EVAP1,WLSM1
      READ(5,500) AWLCU1,AWLSM1,WLDEF1
      READ(5,500) WLAGW1,TSWL1,SIMP1
      READ(5,500)EMID1,EMIR1,WLSFC1
      READ(5,500)STIF1,GWTS1,SINT1
  500 FORMAT(15A5)
      READ(5,501) VAR1
  501 FORMAT(13A6)
      CV=43560./(3600.*24.)
      W(1)=CV/31.
      W(2)=CV/30.
      W(3)=W(1)
      W(4)=W(1)
      W(5)=CV/28.
      W(6)=W(1)
      W(7)=W(2)
      W(8)=W(1)
      W(9)=W(2)
      W(10)=W(1)
      W(11)=W(1)
      W(12)=W(2)
      W(13)=CV/365.
    1 READ(5,101)  NAME
  101 FORMAT (20A4)
C
C     READ INITIALIZATION PARAMETERS
      READ(5,102)STA,NYR,IM,NC1,NC2,NRC,NPR,NRIF,NCD,NPW,NMID,NMI,NTIF,
     1NSIMP,NRES,NEXPO,NGFLO,NGWOF,IG,NCU,EFOF,EFCV,CC,CW,CT,EKGW,EKS,
     2TP,TSM
  102 FORMAT(A6,18I2,I1,2F3.2,3F5.3,2F4.3,2F4.1)
      READ(5,103) STA1,TAC,TAWL,RESF,ASMS(1,1),RZD,SMC1,SSO,SGW(1,1),
     1GWC,TKGW,GWCAP
  103 FORMAT(A6,3F8.0,F6.0,3F5.2,2F8.0,F5.3,F8.0)
      READ(5,107) STA2,NOO,CPR,WGWK,TARES,AWLSM(1,1),WLSMC
  107 FORMAT(A6,I4,2F5.3,3F10.0)
C
C     READ INITIALIZATION COEFFICIENTS FOR TRANSITIONAL GW STORAGE
C
      IF(IG.EQ.0) GO TO 2
      READ(5,104)(SKW(I),I=1,IG)
  104 FORMAT(14X12F5.3)
    2 ZIM=IM
      ENYR = NYR
      NT= NYR +1
      NSD=NT+1
      INT = IM +1
C
C     READ CROPLAND GROUNDWATER RETURN FLOW COEFFICIENTS
C
      READ(5,104)(RTK(I),I=1,IM)
C
C     READ SURFACE UNMEASURED INFLOW COEFFICIENTS
C
      READ(5,104)(STFK(I),I=1,IM)
C
C     READ INTERFLOW SUPPLY TO WETLAND COEFFICIENTS
C
      READ(5,104)(SWLK(I),I=1,IM)
C
C      READ PROPORTION OF DAYLIGHT HOURS
C
      READ(5,130) (POH(I), I=1,IM)
  130 FORMAT(14X12F5.4)
C
C     READ PROPORTION CROP AREAS AND GROWTH STAGE COEFFICIENTS
C
      IF(NC1) 10,10,5
    5 READ(5,106)(PAC1(J), J=1,NC1)
  106 FORMAT(10X,13F5.3)
      DO 6 J=1,NC1
      READ(5,105)CROP(J),(AGSC(I,J),I=1,IM)
  105 FORMAT(8XA6,12F5.2)
    6 AC1(J) = TAC*PAC1(J)
C
C     READ PROPORTION PHREATOPHYTE AREAS AND GROWTH STAGE COEFFICIENTS
C
   10 IF(NC2) 15,15,11
   11 READ(5,106) (PAC2(J), J=1,NC2)
      DO 12 J=1,NC2
      READ(5,105)PHP(J),(PGSC(I,J),I=1,IM)
   12 AC2(J)= TAWL*PAC2(J)
C
C     READ RESERVOIR WATER GROWTH STAGE COEFFICIENTS
C
   15 IF(NRES.NE.0) READ(5,105) WTR,(WGSC(I),I=1,IM)
C
C     READ INPUT DATA
C
      READ(5,1000)(LYR(J),J=1,NSD)
 1000 FORMAT(10X,14A5)
C
C     CALCULATE CROPLAND SOIL MOISTURE CAPACITY AND INITIAL SNOW
C     STORAGE ON THE CROPLAND AND WETLAND
C
      SMC=RZD*SMC1*TAC/12.
      SSC(1,1)=SSO*TAC/12.
      SSW(1,1)=SSO*TAWL/12.
C
C     PRINT ORIGINAL INPUT DATA IF NPR NE 0
C
      IF(NPR.EQ.0) GO TO 13
      WRITE(6,507) NAME
  507 FORMAT(15H1INPUT DATA FOR,20A4)
      WRITE(6,508)STA,NYR,IM,NC1,NC2,NRC,NPR,NRIF,NCD,NPW,NMID,NMI,NTIF,
     1NSIMP,NRES,NEXPO,NGFLO,NGWOF,IG,NCU,EFOF,EFCV,CC,CW,CT,EKGW,EKS,
     2TP,TSM
  508 FORMAT(1XA6,19I3,2F5.2,3F6.3,2F6.3,2F6.1)
      WRITE(6,509)STA1,TAC,TAWL,RESF,ASMS(1,1),RZD,SMC1,SSO,SGW(1,1),GWC
     1,TKGW,GWCAP,SMC,SSC(1,1),SSW(1,1)
  509 FORMAT(1XA6,3F10.0,F8.0,3F6.2,2F10.0,F8.3,4F10.0)
      WRITE(6,701)STA2,NOO,CPR,WGWK,TARES,AWLSM(1,1),WLSMC
  701 FORMAT(1XA6,I4,2F10.3,3F10.0)
   13 IF(IG.EQ.0) GO TO 14
      SKW(IG+1)=1.
      DO 7 I=1,IG
    7 SKW(IG+1)=SKW(IG+1)-SKW(I)
      IF(NPR.NE.0)WRITE(6,511)(SKW(I),I=1,IG),SKW(IG+1)
  511 FORMAT(1X'INTERFLOW GW STORAGE COEF',13F8.3)
      DO 8 I=1,IG
    8 STW(I)=SKW(I)*SGW(1,1)
      TRI=SGW(1,1)*SKW(IG+1)
      IF(NPR.NE.0)WRITE(6,512)(STW(I),I=1,IG),TRI
  512 FORMAT(1X'INITIAL INTERFLOW STORAGE',12F8.3)
   14 IF(NPR.EQ.0) GO TO 600
      WRITE(6,560) LYR(1),VAR1
      WRITE(6,510)(RTK(I),I=1,IM)
  510 FORMAT(1X25HCROP GW-RETURN FLO COEF  ,12F8.3)
      WRITE(6,517)(STFK(I),I=1,IM)
  517 FORMAT(1X25HSURFACE TIF COEFFICIENTS ,12F8.3)
      WRITE(6,700) (SWLK(I),I=1,IM)
  700 FORMAT(1X'INTERFLOW SWL COEF',7X,12F8.3)
      WRITE(6,502)(POH(I),I=1,IM)
  502 FORMAT(1X25HPROPORTION DAYLIGHT HOURS,12F8.4)
      IF(NC1.EQ.0) GO TO 91
      WRITE(6,503)(PAC1(J),J=1,NC1)
  503 FORMAT(1X'PROP CROP AREAS',14F8.3)
      WRITE(6,520)(AC1(J),J=1,NC1),TAC
  520 FORMAT(6X'CROP AREAS',14F8.0)
      WRITE(6,504)(J,CROP(J),(AGSC(I,J),I=1,IM),J=1,NC1)
  504 FORMAT(1XI3,1XA6,7H K COEF,8X,12F8.2)
   91 IF(NC2.EQ.0) GO TO 93
      WRITE(6,505)(PAC2(J),J=1,NC2)
  505 FORMAT(1X'PROP WLPH AREAS',14F8.3)
      WRITE(6,521)(AC2(J),J=1,NC2),TAWL
  521 FORMAT(6X'WLPH AREAS',14F8.0)
      WRITE(6,504)(J,PHP(J),(PGSC(I,J),I=1,IM),J=1,NC2)
   93 IF(NRES.NE.0)WRITE(6,522)WTR,(WGSC(I),I=1,IM)
  522 FORMAT(1H0A6,7H K COEF,11X12F8.2)
      IF(NRIF.NE.0.AND.NPR.NE.0)WRITE(6,506)RIF1
  506 FORMAT(25X5A6)
  600 CALL INPUT( NRIF, NYR, IM, RIF,NPR)
      IF(NSIMP.NE.0.AND.NPR.NE.0)WRITE(6,506)SIMP1
      CALL INPUT(NSIMP,NYR,IM,SIMP,NPR)
      IF(NCD.NE.0.AND.NPR.NE.0)WRITE(6,506)CD1
      CALL INPUT(NCD, NYR, IM, CD,NPR)
      IF(NPW.NE.0.AND.NPR.NE.0)WRITE(6,506)PW1
      CALL INPUT(NPW, NYR, IM, PW,NPR)
      IF(NPR.NE.0)WRITE(6,506)PREC1
      CALL INPUT(1, NYR, IM, PREC,NPR)
      IF(NPR.NE.0)WRITE(6,506)TEMP1
      CALL INPUT(1, NYR, IM, TEMP,NPR)
      IF(NMID.NE.0.AND.NPR.NE.0)WRITE(6,506)EMID1
      CALL INPUT(NMID,NYR,IM,EMID,NPR)
      IF(NMI.NE.0.AND.NPR.NE.0)WRITE(6,506)EMI1
      CALL INPUT(NMI, NYR, IM, EMI,NPR)
      IF(NTIF.NE.0.AND.NPR.NE.0)WRITE(6,506)TIF1
      CALL INPUT(NTIF, NYR, IM, TIF,NPR)
      IF(NRES.NE.0.AND.NPR.NE.0)WRITE(6,506)RES1
      CALL INPUT(NRES, NYR, IM, RES,NPR)
      IF(NEXPO.NE.0.AND.NPR.NE.0)WRITE(6,506)EXPO1
      CALL INPUT(NEXPO,NYR,IM,EXPO,NPR)
      IF(NGFLO.NE.0.AND.NPR.NE.0) WRITE(6,506) GFLO1
```

Figure G-5. Listing of program BUDGET with deck setup.

```
      CALL INPUT(NGFLO,NYR,IM,GFLO,NPR)
      IF(NGWOF.NE.0.AND.NPR.NE.0) WRITE(6,506) GWOF1
      CALL INPUT(NGWOF,NYR,IM,GWOF,NPR)
C
C     INITIALIZATION OF ANNUAL COLUMN AND TOTALS FOR ITEMS NOT CALLED
C     BY SUBROUTINE INPUT
C
      LK = 1
      JB = 1
      IB = IMT
   18 DO 24 J=JB,NSD
      ERR(J)=0.
      DO 24 I=IB, IMT
      SSC(I,J)=0.
      SSW(I,J)=0.
      SMA(I,J)=0.
      SMW(I,J)=0.
      DSC(I,J)=0.
      DSW(I,J)=0.
      SGW(I,J)=0.
      DGW(I,J)=0.
      DCG(I,J)=0.
      DRES(I,J)= 0.
      USW(I,J)= 0.
      EMIR(I,J)=0.
      IF(LK.EQ.1.AND.I.EQ.IMT) GO TO 602
      RIF(I,J) =0.
      SIMP(I,J)=0.
      TIF(I,J)= 0.
      CD(I,J) =0.
      PW(I,J)=0.
      EMID(I,J)=0.
      EMI(I,J)=0.
      RES(I,J)= 0.
      EXPO(I,J)=0.
      GFLO(I,J)=0.
  602 DWRZ(I,J)=0.
      GWOF(I,J)=0.
      GWIN(I,J)=0.
      STIF(I,J)=0.
      SINT(I,J)=0.
      PCL(I,J)=0.
      TSRZ(I,J)=0.
      SPCU(I,J)=0.
      SMS(I,J)=0.
      ASMS(I,J)=0.
      DEF(I,J)=0.
      ACU(I,J)=0.
      AGW(I,J)=0.
      RTFLO(I,J)=0.
      SWL(I,J)=0.
      PWL(I,J)=0.
      SWLCU(I,J)=0.
      TAVE(I,J)=0.
      F(I,J)=0.
      SOF(I,J)=0.
      TOF(I,J)=0.
      GWRT(I,J)=0.
      SRTF(I,J)=0.
      GWTS(I,J)=0.
      PRES(I,J)=0.
      EVAP(I,J)=0.
      WEVAP(I,J)=0.
      WLSM(I,J)=0.
      AWLSM(I,J)=0.
      TGWA(I,J)=0.
      WLAGW(I,J)=0.
      DELGW(I,J)=0.
      WLSFC(I,J)=0.
      IF(NC1) 21,21,19
   19 DO 20 K=1,NC1
      PCUU(I,J,K) =0.
   20 PCU(I,J,K) =0.
   21 IF(NC2) 24,24,22
   22 DO 23 K=1,NC2
      WLCUU(I,J,K) =0.
   23 WLCU(I,J,K) = 0.
      AWLCU(I,J)=0.
   24 CONTINUE
      GO TO (25,26),LK
   25 JB=NT
      IB=1
      LK=2
      GO TO 18
C
C     CALCULATE CHANGE IN RESERVIOR STORAGE,RES(I,J) IS STORAGE AT THE
C     END OF PERIOD I, YEAR J
C
   26 DO 17 J=1,NYR
      DRES(1,J)=RES(1,J)-RESF
      DO 16 I=2,IM
   16 DRES(I,J)=RES(I,J)-RES(I-1,J)
      RES(IMT,J)=RES(IM,J)
      DRES(IMT,J)=RES(IM,J)-RESF
   17 RESF=RES(IM,J)
C
C     BUDGET CALCULATIONS BEGIN HERE
C
      EKT=1.
      DO 75 J=1,NYR
      IF(J.EQ.1) GO TO 300
C
C     ESTABLISH INITIAL STORAGE CONDITIONS FOR ALL YEARS AFTER YEAR 1
C
      AWLSM(1,J)=AWLSM(IMT,J-1)
      ASMS(1,J)=ASMS(IMT,J-1)
      SSC(1,J)=SSC(IMT,J-1)
      SSW(1,J)=SSW(IMT,J-1)
      SGW(1,J)=SGW(IMT,J-1)
      IF(IG.EQ.0) GO TO 300
      DO 39 I=1,IG
   39 SKW(I)=STW(I)/SGW(1,J)
      SKW(IG+1)=TRI/SGW(1,J)
      WRITE(6,513)LYR(J),(SKW(I),I=1,IG),SKW(IG+1)
  513 FORMAT(1X'INTFLO COEF FOR YEAR',A5,11F7.3)
      WRITE(6,514)LYR(J),(STW(I),I=1,IG),TRI,SGW(1,J)
  514 FORMAT(1X'INIT INTFLO FOR YEAR',A5,14F7.3)
  300 I=0
  601 I=I+1
      IF(I.EQ.IMT) GO TO 50
C
C     CALCULATE POTENTIAL CONSUMPTIVE USE
C
      TAVE(I,J) = CT*TEMP(I,J)
      F(I,J)=TAVE(I,J)*PDM(I)
      IF(NBC.NE.0) EKT=.0173*TAVE(I,J)-.314
      IF(EKT.LT..3)EKT=.3
      SPCU(I,J)=0.
      IF(NC1) 29,29,27
   27 DO 28 K=1,NC1
      PCUU(I,J,K)=F(I,J)*EKT*AOSC(I,K)
      PCU(I,J,K) = PCUU(I,J,K)*AC1(K)/12.
   28 SPCU(I,J) =SPCU(I,J)+PCU(I,J,K)
   29 SWLCU(I,J)=0.
      IF(NC2) 32,32,30
   30 DO 31 K=1, NC2
      WLCUU(I,J,K)= F(I,J)*EKT*PGSC(I,K)
      WLCU(I,J,K) = WLCUU(I,J,K) *AC2(K)/12.
   31 SWLCU(I,J) = SWLCU(I,J)+WLCU(I,J,K)
C
C     CALCULATE PRECIPITATION AND EVAPORATION FROM RESERVIORS
C
   32 EVAP(I,J)=0.
      WEVAP(I,J)=0.
      PRES(I,J)=0.
      IF(NRES.EQ.0) GO TO 605
      WEVAP(I,J)=F(I,J)*EKT*WGSC(I)
      EVAP(I,J)=WEVAP(I,J)*TARES/12.
      PRES(I,J)= PREC(I,J)*CPR*TARES/12.
C
C     CALCULATE SNOW STORAGE AND SNOW MELT
C
  605 PCL(I,J)=PREC(I,J)*CC*TAC/12.
      PWL(I,J)=PREC(I,J)*CW*TAWL/12.
      IF(TAVE(I,J).GT.TP) GO TO 301
      DSC(I,J)=PCL(I,J)
      DSW(I,J)=PWL(I,J)
      GO TO 302
  301 DSC(I,J)=0.
      DSW(I,J)=0.
  302 SSC(I+1,J)=SSC(I,J)+DSC(I,J)
      SSW(I+1,J)=SSW(I,J)+DSW(I,J)
      IF(TAVE(I,J).GT.TSM) GO TO 305
      SMA(I,J)=0.
      SMW(I,J)=0.
      GO TO 310
  305 SMA(I,J)=EKS*(TAVE(I,J)-TSM)*SSC(I+1,J)
      SMW(I,J)=EKS*(TAVE(I,J)-TSM)*SSW(I+1,J)
      IF(SMA(I,J).GT.SSC(I+1,J)) SMA(I,J)=SSC(I+1,J)
      IF(SMW(I,J).GT.SSW(I+1,J))  SMW(I,J)=SSW(I+1,J)
  310 SSC(I+1,J)=SSC(I+1,J)-SMA(I,J)
      SSW(I+1,J)=SSW(I+1,J)-SMW(I,J)
C
C     CALCULATE SURFACE AND GW UNMEASURED INFLOW
C
      STIF(I,J)=TIF(I,J)*STFK(I)
      GWIN(I,J)=TIF(I,J)-STIF(I,J)
C
C     CALCULATE ROOT ZONE SUPPLY
C
      DWRZ(I,J)= CD(I,J)*EFCV*EFOF
      TSRZ(I,J)=DWRZ(I,J)+PCL(I,J)-DSC(I,J)+SMA(I,J)
      SMS(I,J)= TSRZ(I,J)- SPCU(I,J)
      RTFLO(I,J)=CD(I,J)-DWRZ(I,J)
      GWRT(I,J)=RTK(I)*RTFLO(I,J)
      SRTF(I,J)=RTFLO(I,J)-GWRT(I,J)
      IF(SMS(I,J)) 33,33,35
   33 IF(SMS(I,J)+ASMS(I,J)) 34,34,35
   34 ASMS(I+1,J) =0.
      AGW(I,J)=0.
      DEF(I,J)=SMS(I,J)+ASMS(I,J)
      ACU(I,J)= SPCU(I,J) + DEF(I,J)
      GO TO 45
   35 ASMS(I+1,J)= ASMS(I,J)+SMS(I,J)
      IF(ASMS(I+1,J)- SMC) 38,38,40
   38 AGW(I,J)=0.
      GO TO 43
   40 AGW(I,J)= ASMS(I+1,J)-SMC
      ASMS(I+1,J) = SMC
   43 ACU(I,J) = SPCU(I,J)
      DEF(I,J)=0.
C
C     CALCULATE INTERFLOW GW STORAGE CHANGES, INTERFLOW TO SURFACE
C     WATER, AND INTERFLOW ADDITION TO GROUNDWATER
C
   45 GIN=AGW(I,J)+GWRT(I,J)+GWIN(I,J)
      EKGW2=EKGW+2.
      SINT(I,J)=0.
      IF(IG.EQ.0)GO TO 66
      DGW(I,J)=(TRI+TRI+STW(IG))*EKGW/EKGW2
      IF(DGW(I,J).GT.GWC)GO TO 62
      DGW(I,J)=GWC
      IF(TRI+STW(IG).LT.DGW(I,J))DGW(I,J)=TRI+STW(IG)
   62 TRI= TRI+STW(IG)-DGW(I,J)
      IF(IG.EQ.1)GO TO 65
      DO 63 K=IG,2,-1
   63 STW(K)=STW(K-1)
   65 SGW(I+1,J)=SGW(I,J)+GIN-DGW(I,J)
      GO TO 67
   66 SGW(I+1,J)=((2.-EKGW)*SGW(I,J)+GIN+GIN)/EKGW2
      IF(SGW(I+1,J).LE.GWCAP) GO TO 46
      SGW(I+1,J)=GWCAP
```

Figure G-5. Continued.

```
      DGW(I,J)=(SGW(I,J)+GWCAP)*.5*EKGW
      SINT(I,J)=SGW(I,J)+GIN-DGW(I,J)-GWCAP
      GO TO 64
   46 DGW(I,J)=(SGW(I,J)+SGW(I+1,J))*.5*EKGW
   64 IF(DGW(I,J).GE.GWC)GO TO 67
      DGW(I,J)=GWC
      SGW(I+1,J)=SGW(I,J)+GIN-GWC
      IF(SGW(I+1,J).GE.0.)GO TO 67
      SGW(I+1,J)=0.
      DGW(I,J)=SGW(I,J)+GIN
      GO TO 68
   67 IF(SGW(I+1,J).LE.GWCAP) GO TO 68
      SINT(I,J)=SGW(I+1,J)-GWCAP
      SGW(I+1,J)=GWCAP
   68 STW(I)=GIN-SINT(I,J)
      WLAGW(I,J)=0.
      WLSFC(I,J)=0.
      IF(NC2.EQ.0) GO TO 650
C
C     CALCULATE WETLAND ROOT ZONE STORAGE, CONSUMPTIVE USE, WETLAND
C     SURFACE AND GW OVERFLOW AND SURFACE SUPPLY IN CHANNEL
C
      SWL(I,J)= SWLK(I)*SINT(I,J)
      SINT(I,J)= SINT(I,J)-SWL(I,J)
      TSWL(I,J)=SWL(I,J)+PWL(I,J)-DSW(I,J)+SMW(I,J)
      WLSM(I,J)=TSWL(I,J)-SWLCU(I,J)
      IF(WLSM(I,J)) 615,615,620
  615 IF(WLSM(I,J)+AWLSM(I,J)) 616,616,620
  616 AWLSM(I,J)=0.
      WLAGW(I,J)=0.
      WLDEF(I,J)=WLSM(I,J)+AWLSM(I,J)
      AWLCU(I,J)= SWLCU(I,J)+ WLDEF(I,J)
      GO TO 650
  620 AWLSM(I+1,J)= AWLSM(I,J)+ WLSM(I,J)
      IF(AWLSM(I+1,J)-WLSMC) 625,625,630
  625 WLAGW(I,J)=0.
      GO TO 635
  630 WLAGW(I,J)= AWLSM(I+1,J)- WLSMC
      AWLSM(I+1,J)= WLSMC
  635 AWLCU(I,J)= SWLCU(I,J)
      WLDEF(I,J)=0.
C
C     SEPARATE WLAGW INTO SURFACE AND GW COMPONENTS
C
  650 GWWL =(AWLSM(I,J)+AWLSM(I+1,J))*.5*WGWK
      WLSFC(I,J)=WLAGW(I,J)-GWWL
      IF(WLSFC(I,J))651,652,652
  651 WLSFC(I,J)=0.
      GO TO 653
  652 WLAGW(I,J)=GWWL
C
C     CALCULATE GWTS,EMIR,USW,SOF,TGWA,TOF,DCG,ERR1
C
  653 GWTS(I,J)=SINT(I,J)+WLSFC(I,J)
      EMIR(I,J)=EMID(I,J)-EMI(I,J)
      USW(I,J)=RIF(I,J)+STIF(I,J)+PRES(I,J)+PW(I,J)-EVAP(I,J)+RES(I,J)-
     1DRES(I,J)+SRTF(I,J)+EMIR(I,J)+GWTS(I,J)+SIMP(I,J)
      SOF(I,J)=USW(I,J)-RES(I,J)-CD(I,J)-EXPO(I,J)-EMID(I,J)
      TGWA(I,J)=WLAGW(I,J)+DGW(I,J)
      TOF(I,J)=SOF(I,J)+TGWA(I,J)-PW(I,J)
      DCG(I,J)=SOF(I,J)-GFLO(I,J)
      ERR1(J)=ERR1(J)+ABS(DCG(I,J))
C
C     CALCULATE ANNUAL VALUES FOR YEAR J FOR VARIABLES NOT READ IN BY
C     SUBROUTINE INPUT
C
      DCG(IMT,J)=DCG(IMT,J)+DCG(I,J)
      EMIR(IMT,J)=EMIR(IMT,J)+EMIR(I,J)
      IF(NRES.EQ.0) GO TO 660
      PRES(IMT,J)= PRES(IMT,J)+PRES(I,J)
      WEVAP(IMT,J)=WEVAP(IMT,J)+WEVAP(I,J)
      EVAP(IMT,J)= EVAP(IMT,J)+EVAP(I,J)
  660 PCL(IMT,J)=PCL(IMT,J)+PCL(I,J)
      STIF(IMT,J)=STIF(IMT,J)+STIF(I,J)
      GWIN(IMT,J)=GWIN(IMT,J)+GWIN(I,J)
      SINT(IMT,J)=SINT(IMT,J)+SINT(I,J)
      TGWA(IMT,J)=TGWA(IMT,J)+TGWA(I,J)
      SMS(IMT,J)=SMS(IMT,J)+SMS(I,J)
      TAVE(IMT,J)=TAVE(IMT,J)+TAVE(I,J)/ZIM
      F(IMT,J)=F(IMT,J)+F(I,J)
      DWRZ(IMT,J) = DWRZ(IMT,J)+ DWRZ(I,J)
      GWRT(IMT,J)=GWRT(IMT,J)+GWRT(I,J)
      SRTF(IMT,J)=SRTF(IMT,J)+SRTF(I,J)
      TSRZ(IMT,J)= TSRZ(IMT,J)+TSRZ(I,J)
      RTFLO(IMT,J)= RTFLO(IMT,J)+ RTFLO(I,J)
      DEF(IMT,J)= DEF(IMT,J) + DEF(I,J)
      SPCU(IMT,J)= SPCU(IMT,J)+ SPCU(I,J)
      ACU(IMT,J)= ACU(IMT,J) + ACU(I,J)
      AGW(IMT, J)= AGW(IMT,J)+ AGW(I,J)
      SWLCU(IMT,J)= SWLCU(IMT,J)+ SWLCU(I,J)
      PWL(IMT,J) = PWL(IMT,J)+ PWL(I,J)
      TOF(IMT,J)=TOF(IMT,J)+TOF(I,J)
      DSC(IMT,J)=DSC(IMT,J)+DSC(I,J)
      DSW(IMT,J)=DSW(IMT,J)+DSW(I,J)
      SMA(IMT,J)=SMA(IMT,J)+SMA(I,J)
      SMW(IMT,J)=SMW(IMT,J)+SMW(I,J)
      DGW(IMT,J)=DGW(IMT,J)+DGW(I,J)
      SWL(IMT,J)= SWL(IMT,J)+SWL(I,J)
      TSWL(IMT,J)= TSWL(IMT,J)+TSWL(I,J)
      GWTS(IMT,J)= GWTS(IMT,J)+GWTS(I,J)
      USW(IMT,J)= USW(IMT,J)+USW(I,J)
      SOF(IMT,J)=SOF(IMT,J)+SOF(I,J)
      WLSFC(IMT,J)=WLSFC(IMT,J)+WLSFC(I,J)
      IF(NC1.EQ.0) GO TO 48
      DO 47 K=1,NC1
      PCUU(IMT,J,K)= PCUU(IMT,J,K)+ PCUU(I,J,K)
   47 PCU(IMT,J,K)= PCU(IMT,J,K)+ PCU(I,J,K)
   48 IF(NC2.EQ.0) GO TO 50
      DO 49 L=1,NC2
      WLCUU(IMT,J,L)= WLCUU(IMT,J,L)+WLCUU(I,J,L)
   49 WLCU(IMT,J,L)= WLCU(IMT,J,L)+ WLCU(I,J,L)
      AWLCU(IMT,J)= AWLCU(IMT,J)+AWLCU(I,J)
      WLSM(IMT,J)= WLSM(IMT,J)+WLSM(I,J)
      WLAGW(IMT,J)= WLAGW(IMT,J)+WLAGW(I,J)
      WLDEF(IMT,J)= WLDEF(IMT,J)+WLDEF(I,J)
   50 IF(NYR.EQ.1) GO TO 60
C
C     ACCUMULATE TOTALS FOR EACH MONTH OVER ALL YEARS
C
      IF(NRES.EQ.0) GO TO 51
      PRES(I,NT)= PRES(I,NT)+PRES(I,J)
      WEVAP(I,NT)=WEVAP(I,NT)+WEVAP(I,J)
      EVAP(I,NT)= EVAP(I,NT)+EVAP(I,J)
   51 RIF(I,NT)= RIF(I,NT)+RIF(I,J)
      SIMP(I,NT)=SIMP(I,NT)+SIMP(I,J)
      STIF(I,NT)=STIF(I,NT)+STIF(I,J)
      SINT(I,NT)=SINT(I,NT)+SINT(I,J)
      TGWA(I,NT)=TGWA(I,NT)+TGWA(I,J)
      DCG(I,NT)=DCG(I,NT)+DCG(I,J)
      PREC(I,NT)=PREC(I,NT)+PREC(I,J)
      EMIR(I,NT)=EMIR(I,NT)+EMIR(I,J)
      SOF(I,NT)=SOF(I,NT)+SOF(I,J)
      WLSFC(I,NT)=WLSFC(I,NT)+WLSFC(I,J)
      CD(I,NT)=CD(I,NT)+CD(I,J)
      PW(I,NT)=PW(I,NT)+PW(I,J)
      PCL(I,NT)=PCL(I,NT)+PCL(I,J)
      SMS(I,NT)=SMS(I,NT)+SMS(I,J)
      TAVE(I,NT)=TAVE(I,NT)+TAVE(I,J)
      F(I,NT)=F(I,NT)+F(I,J)
      GFLO(I,NT)=GFLO(I,NT)+GFLO(I,J)
      GWRT(I,NT)=GWRT(I,NT)+GWRT(I,J)
      SRTF(I,NT)=SRTF(I,NT)+SRTF(I,J)
      TOF(I,NT)=TOF(I,NT)+TOF(I,J)
      USW(I,NT)=USW(I,NT)+USW(I,J)
      DWRZ(I,NT)= DWRZ(I,NT)+DWRZ(I,J)
      TSRZ(I,NT)= TSRZ(I,NT)+ TSRZ(I,J)
      RTFLO(I,NT)= RTFLO(I,NT)+ RTFLO(I,J)
      DEF(I,NT)= DEF(I,NT)+ DEF(I,J)
      SPCU(I,NT)= SPCU(I,NT)+ SPCU(I,J)
      EXPO(I,NT)= EXPO(I,NT)+ EXPO(I,J)
      ACU(I,NT)= ACU(I,NT)+ ACU(I,J)
      AGW(I,NT)= AGW(I,NT)+ AGW(I,J)
      SWLCU(I,NT)= SWLCU(I,NT)+ SWLCU(I,J)
      PWL(I,NT)= PWL(I,NT)+ PWL(I,J)
      EMID(I,NT)=EMID(I,NT)+EMID(I,J)
      EMI(I,NT)= EMI(I,NT)+ EMI(I,J)
      TIF(I,NT)= TIF(I,NT)+ TIF(I,J)
      GWIN(I,NT)=GWIN(I,NT)+GWIN(I,J)
      SWL(I,NT)= SWL(I,NT)+ SWL(I,J)
      ASMS(I,NT)=ASMS(I,NT)+ASMS(I,J)
      RES(I,NT)=RES(I,NT)+RES(I,J)
      DRES(I,NT)=DRES(I,NT)+DRES(I,J)
      SGW(I,NT)=SGW(I,NT)+SGW(I,J)
      DGW(I,NT)=DGW(I,NT)+DGW(I,J)
      SSC(I,NT)=SSC(I,NT)+SSC(I,J)
      SSW(I,NT)=SSW(I,NT)+SSW(I,J)
      SMA(I,NT)=SMA(I,NT)+SMA(I,J)
      SMW(I,NT)=SMW(I,NT)+SMW(I,J)
      DSC(I,NT)=DSC(I,NT)+DSC(I,J)
      DSW(I,NT)=DSW(I,NT)+DSW(I,J)
      TSWL(I,NT)= TSWL(I,NT)+ TSWL(I,J)
      GWTS(I,NT)= GWTS(I,NT)+ GWTS(I,J)
      IF(NC1) 57,57,52
   52 DO 55 K=1,NC1
      PCUU(I,NT,K)= PCUU(I,NT,K)+ PCUU(I,J,K)
   55 PCU(I,NT,K)= PCU(I,NT,K)+ PCU(I,J,K)
   57 IF(NC2)60,60,58
   58 DO 59 K=1,NC2
      WLCUU(I,NT,K)= WLCUU(I,NT,K)+ WLCUU(I,J,K)
   59 WLCU(I,NT,K)= WLCU(I,NT,K)+ WLCU(I,J,K)
      AWLCU(I,NT)= AWLCU(I,NT)+ AWLCU(I,J)
      WLSM(I,NT)= WLSM(I,NT)+ WLSM(I,J)
      WLAGW(I,NT)= WLAGW(I,NT)+WLAGW(I,J)
      WLDEF(I,NT)= WLDEF(I,NT)+WLDEF(I,J)
      AWLSM(I,NT)= AWLSM(I,NT)+AWLSM(I,J)
   60 IF(I.NE.IMT) GO TO 601
      ERR1(NT)=ERR1(NT)+ERR1(J)
C
C     CALCULATE GW OUTFLOW AND CHANGE IN GW STORAGE FOR EACH MONTH
C
      IF(NGWOF.NE.0)GO TO 72
      GWOF(IMT,J)=TKGW*TOF(IMT,J)
      DGX= DGW(IMT,J)+WLAGW(IMT,J)
      IF(DGX.LE.0) DGX=1.
      PKGW= GWOF(IMT,J)/DGX
   72 DO 61 I=1,IM
      IF(NGWOF.NE.0) GO TO 73
      GWOF(I,J)=(DGW(I,J)+WLAGW(I,J))*PKGW
      GO TO 74
   73 GWOF(IMT,J)=GWOF(IMT,J)+GWOF(I,J)
   74 GWOF(I,NT)=GWOF(I,NT)+GWOF(I,J)
      DELGW(I,J)=WLAGW(I,J)+DGW(I,J)-PW(I,J)-GWOF(I,J)
   61 DELGW(I,NT)=DELGW(I,NT)+DELGW(I,J)
C
C     CALCULATE ANNUAL VALUES AND ACCUMULATE SUM FOR GWOF AND DELGW
C
      GWOF(IMT,NT)=GWOF(IMT,NT)+GWOF(IMT,J)
      DELGW(IMT,J)=WLAGW(IMT,J)+DGW(IMT,J)-PW(IMT,J)-GWOF(IMT,J)
      DELGW(IMT,NT)=DELGW(IMT,NT)+DELGW(IMT,J)
   75 CONTINUE
C
C     CALCULATE FINAL TRANSIENT GROUNDWATER STORAGE COEFFICIENTS AND
C     AMOUNTS IN INTERFLOW STORAGE
C
      IF(IG.EQ.0) GO TO 80
      DO 79 I=1,IG
   79 SKW(I)=STW(I)/SGW(IMT,NYR)
      SKW(IG+1)=TRI/SGW(IMT,NYR)
      WRITE(6,515)(SKW(I),I=1,IG),SKW(IG+1)
  515 FORMAT(1H0*FINAL INTERFLOW GW COFF*,2X,13F7.3)
      WRITE(6,516)(STW(I),I=1,IG),TRI,SGW(IMT,NYR)
  516 FORMAT(1X*FINAL INTFLO GW STORAGE*,2X,14F7.0)
```

Figure G-5. Continued.

```
C
C      OUTPUT OF MASS BALANCE WATER BUDGET
C
   80 IF(NYR-1)76,76,77
   76 L=2
      GO TO 78
   77 L=1
   78 JB=1
      JN=NYR
  100 DO 200 J=JB,JN
      WRITE(6,1001)NAME
 1001 FORMAT(1H1,25X,20A4)
      WRITE(6,560)LYR(J),VAR1
  560 FORMAT(11H ITEM--YEAR,A5,11X,13(2X,A6))
  550 FORMAT(1H ,5A5,12F8.0,F9.0)
      WRITE(6,550)  RIF1, (RIF(I,J), I=1,IMT)
      IF(NSIMP.NE.0)WRITE(6,550)SIMP1,(SIMP(I,J),I=1,IMT)
      WRITE(6,550) TIF1, (TIF(I,J), I=1,IMT)
      WRITE(6,550)STIF1,(STIF(I,J),I=1,IMT)
      WRITE(6,550)GWIN1,(GWIN(I,J),I=1,IMT)
      IF(NRES.EQ.0) GO TO 125
      WRITE(6,550) RES1,(RES(I,J), I=1,IMT)
      WRITE(6,550) PRES1, (PRES(I,J),I=1,IMT)
      WRITE(6,550) EVAP1,( EVAP(I,J),I=1,IMT)
      WRITE(6,550) DRES1, (DRES(I,J),I=1,IMT)
  125 IF(NPW.NE.0)WRITE(6,550)PW1,(PW(I,J),I=1,IMT)
      IF(NC1.NE.0)WRITE(6,550)SRTF1,(SRTF(I,J),I=1,IMT)
      WRITE(6,550) GWTS1,(GWTS(I,J),I=1,IMT)
      IF(NMI.NE.0)WRITE(6,550)EMIR1,(EMIR(I,J),I=1,IMT)
      WRITE(6,550) USW1, (USW(I,J), I=1,IMT)
      IF(NEXPO.NE.0)WRITE(6,550)EXPO1,(EXPO(I,J),I=1,IMT)
      IF(NMI.EQ.0) GO TO 128
      WRITE(6,550)EMID1,(EMID(I,J),I=1,IMT)
      WRITE(6,550) EMI1, (EMI(I,J),I=1,IMT)
  128 IF(NC1.EQ.0) GO TO 127
      WRITE(6,550) CD1, (CD(I,J), I=1,IMT)
      WRITE(6,550) DWRZ1, (DWRZ(I,J), I=1,IMT)
      WRITE(6,550) RTFLO1, (RTFLO(I,J),I=1,IMT)
      WRITE(6,550) PCL1, (PCL(I,J),I=1,IMT)
      WRITE(6,550)DSC1,(DSC(I,J),I=1,IMT)
      WRITE(6,550)SSC1,(SSC(I,J),I=1,IMT)
      WRITE(6,550)SMA1,(SMA(I,J),I=1,IMT)
      WRITE(6,550) TSRZ1, (TSRZ(I,J),I=1,IMT)
      WRITE(6,550) SPCU1, (SPCU(I,J),I=1,IMT)
      WRITE(6,550) SMS1, (SMS(I,J),I=1, IMT)
      WRITE(6,550) ASMS1, (ASMS(I,J),I=1,IMT)
      WRITE(6,550) DEF1, (DEF(I,J),I=1,IMT)
      WRITE(6,550) ACU1, (ACU(I,J),I=1,IMT)
      WRITE(6,550) AGW1, (AGW(I,J),I=1,IMT)
      WRITE(6,550)GWRT1,(GWRT(I,J),I=1,IMT)
  127 WRITE(6,550)SGW1,(SGW(I,J),I=1,IMT)
      WRITE(6,550)SINT1,(SINT(I,J),I=1,IMT)
      IF(NC2.EQ.0) GO TO 126
      WRITE(6,550) SWL1, (SWL(I,J),I=1,IMT)
      WRITE(6,550) PWL1, (PWL(I,J),I=1,IMT)
      WRITE(6,550)DSW1,(DSW(I,J),I=1,IMT)
      WRITE(6,550)SSC1,(SSW(I,J),I=1,IMT)
      WRITE(6,550)SMW1,(SMW(I,J),I=1,IMT)
      WRITE(6,550) TSWL1,( TSWL(I,J),I=1,IMT)
      WRITE(6,550) SWLCU1, (SWLCU(I,J),I=1,IMT)
      WRITE(6,550) WLSM1,( WLSM(I,J),I=1,IMT)
      WRITE(6,550) AWLSM1,( AWLSM(I,J),I=1,IMT)
      WRITE(6,550) WLDEF1,( WLDEF(I,J),I=1,IMT)
      WRITE(6,550) AWLCU1,(AWLCU(I,J),I=1,IMT)
      WRITE(6,550)WLSFC1,(WLSFC(I,J),I=1,IMT)
      WRITE(6,550) WLAGW1,( WLAGW(I,J),I=1,IMT)
  126 WRITE(6,550)DGW1,(DGW(I,J),I=1,IMT)
      WRITE(6,550)TGWA1,(TGWA(I,J),I=1,IMT)
      WRITE(6,550) TOF1,(TOF(I,J),I=1,IMT)
      WRITE(6,550)GWOF1,(GWOF(I,J),I=1,IMT)
      WRITE(6,550)DELGW1,(DELGW(I,J),I=1,IMT)
      WRITE(6,550) SOF1,(SOF(I,J),I=1,IMT)
      IF(NGFLO.EQ.0) GO TO 129
      WRITE(6,550)GFLO1,(GFLO(I,J),I=1,IMT)
      WRITE(6,550)DCG1,(DCG(I,J),I=1,IMT)
      WRITE(6,903) ERR1(J)
  903 FORMAT(1X'SUM OF ABSOLUTE DIFFERENCES =',F16.0)
  129 IF(NCU.EQ.0)GO TO 87
C
C      OUTPUT OF CONSUMPTIVE USE DATA
C
      WRITE(6,1005)
 1005 FORMAT(1H1,50X,28HCONSUMPTIVE USE CALCULATIONS)
      WRITE(6,1006) LYR(J),VAR1
 1006 FORMAT(7X4HYEAR,A5,11X,13(2X,A6))
 1010 FORMAT(1X,5A5,12F8.2,F9.2)
 1011 FORMAT(1XI2,1XA6,15H UNIT USE (IN.),1X12F8.2,F9.2)
 1012 FORMAT(1XI2,1XA6,14H USE (ACRE-FT)7X12F8.0,F9.0)
 1013 FORMAT(1X19HAGRICULTURAL CROPS)
 1014 FORMAT(1X22HWET LAND PHREATOPHYTES)
      WRITE(6,1010)PREC1,(PREC(I,J),I=1,IMT)
      WRITE(6,1010)TEMP1,(TAVE(I,J),I=1,IMT)
      WRITE(6,1010)RCF,(F(I,J),I=1,IMT)
      IF(NC1.EQ.0)GO TO 160
      WRITE(6,1013)
      DO 150 K=1,NC1
      WRITE(6,1011)K,CROP(K),(PCUU(I,J,K),I=1,IMT)
  150 WRITE(6,1012)K,CROP(K),(PCU(I,J,K),I=1,IMT)
      WRITE(6,550) SPCU1,( SPCU(I,J),I=1,IMT)
      WRITE(6,550)ACU1,(ACU(I,J),I=1,IMT)
  160 IF(NC2.EQ.0) GO TO 171
      WRITE(6,1014)
      DO 170 K=1,NC2
      WRITE(6,1011)K,PHR(K),(WLCUU(I,J,K),I=1,IMT)
  170 WRITE(6,1012)K,PHR(K),(WLCU(I,J,K),I=1,IMT)
      WRITE(6,550)SWLCU1,(SWLCU(I,J),I=1,IMT)
      WRITE(6,550) AWLCU1,( AWLCU(I,J),I=1,IMT)
  171 IF(NRES.EQ.0) GO TO 200
      WRITE(6,1010)WEVAP1,(WEVAP(I,J),I=1,IMT)
      WRITE(6,550)EVAP1,(EVAP(I,J),I=1,IMT)
C
```

```
C      CALCULATE AND OUTPUT FLOW VALUES NEEDED FOR WATER QUALITY MODEL
C      IN CFS    NQQ NE 0
C
   87 IF(NQQ.EQ.0) GO TO 200
      DO 91 I=1,IMT
      QI(I)=RIF(I,J)*W(I)
      QS(I)=STIF(I,J)*W(I)
      QRES(I)=(PRES(I,J)-EVAP(I,J)-DRES(I,J))*W(I)
      QPW(I)=PW(I,J)*W(I)
      QGI(I)=GWTS(I,J)*W(I)
      QD(I)=(CD(I,J)+EXPO(I,J)+EMID(I,J))*W(I)
      QIR(I)=SRTF(I,J)*W(I)
      QEF(I)=EMIR(I,J)*W(I)
      QTOF(I)=TOF(I,J)*W(I)
      QGWOF(I)=GWOF(I,J)*W(I)
      QDELGW(I)=DELGW(I,J)*W(I)
      QGFLO(I)=GFLO(I,J)*W(I)
      QDIFF(I)=DCG(I,J)*W(I)
   91 QO(I)=SOF(I,J)*W(I)
      IF(NCU.EQ.0) GO TO 85
      WRITE(6,702)LYR(J)
  702 FORMAT('0'25XA5,2X'FLOW VALUES IN CFS FOR WATER QUALITY MODEL')
      GO TO 89
   85 WRITE(6,704)LYR(J)
  704 FORMAT('1'25XA5,2X'FLOW VALUES IN CFS FOR WATER QUALITY MODEL')
      WRITE(6,1006)LYR(J),VAR1
   89 WRITE(6,703)QI1,LYR(J),(QI(I),I=1,IMT)
  703 FORMAT(1XA5,A5,10X12F8.2,F9.2)
      WRITE(6,703)QS1,LYR(J),(QS(I),I=1,IMT)
      IF(NQQ.GT.1) GO TO 94
      WRITE(6,703)QPW1,LYR(J),(QPW(I),I=1,IMT)
      WRITE(6,703)QRES1,LYR(J),(QRES(I),I=1,IMT)
   94 WRITE(6,703)QGI1,LYR(J),(QGI(I),I=1,IMT)
      WRITE(6,703)QD1,LYR(J),(QD(I),I=1,IMT)
      WRITE(6,703)QIR1,LYR(J),(QIR(I),I=1,IMT)
      WRITE(6,703)QEF1,LYR(J),(QEF(I),I=1,IMT)
      IF(NQQ.GT.1)GO TO 96
      WRITE(6,703)QTOF1,LYR(J),(QTOF(I),I=1,IMT)
      WRITE(6,703)QGWOF1,LYR(J),(QGWOF(I),I=1,IMT)
      WRITE(6,703)QDGW1,LYR(J),(QDELGW(I),I=1,IMT)
   96 WRITE(6,703)QO1,LYR(J),(QO(I),I=1,IMT)
      IF(NGFLO.EQ.0)GO TO 200
      WRITE(6,703)QGFLO1,LYR(J),(QGFLO(I),I=1,IMT)
      WRITE(6,703)QDIFF1,LYR(J),(QDIFF(I),I=1,IMT)
  200 CONTINUE
      GO TO(201,1),L
  201 L=2
      JB=NT
      JN=NSO
C
C      CALCULATE AVERAGES FOR ALL ENTRIES
C
      ERR1(NT)=ERR1(NT)/ENYR
      DO 225 I=1,IMT
      IF(NRES.EQ.0) GO TO 665
      PRES(I,NT)= PRES(I,NT)/ ENYR
      WEVAP(I,NT)=WEVAP(I,NT)/ENYR
      EVAP(I,NT)= EVAP(I,NT)/ENYR
  665 WLSFC(I,NT)=WLSFC(I,NT)/ENYR
      PREC(I,NT)=PREC(I,NT)/ENYR
      SIMP(I,NT)=SIMP(I,NT)/ENYR
      SINT(I,NT)=SINT(I,NT)/ENYR
      STIF(I,NT)=STIF(I,NT)/ENYR
      TGWA(I,NT)=TGWA(I,NT)/ENYR
      DELGW(I,NT)=DELGW(I,NT)/ENYR
      RIF(I,NT)= RIF(I,NT)/ENYR
      CD(I,NT)=CD(I,NT)/ENYR
      PW(I,NT)=PW(I,NT)/ENYR
      PCL(I,NT)=PCL(I,NT)/ENYR
      SMS(I,NT)=SMS(I,NT)/ENYR
      ASMS(I,NT)=ASMS(I,NT)/ENYR
      RES(I,NT)=RES(I,NT)/ENYR
      DRES(I,NT)=DRES(I,NT)/ENYR
      TAVE(I,NT)=TAVE(I,NT)/ENYR
      F(I,NT)=F(I,NT)/ENYR
      USW(I,NT)=USW(I,NT)/ENYR
      DWRZ(I,NT)= DWRZ(I,NT)/ENYR
      TSRZ(I,NT)= TSRZ(I,NT)/ENYR
      RTFLO(I,NT)= RTFLO(I,NT)/ENYR
      SOF(I,NT)=SOF(I,NT)/ENYR
      GFLO(I,NT)=GFLO(I,NT)/ENYR
      DCG(I,NT)=DCG(I,NT)/ENYR
      DEF(I,NT)= DEF(I,NT)/ENYR
      SPCU(I,NT)= SPCU(I,NT)/ENYR
      EXPO(I,NT)= EXPO(I,NT)/ENYR
      ACU(I,NT)= ACU(I,NT)/ENYR
      AGW(I,NT)= AGW(I,NT)/ENYR
      SWLCU(I,NT)= SWLCU(I,NT)/ENYR
      PWL(I,NT)= PWL(I,NT)/ENYR
      EMID(I,NT)=EMID(I,NT)/ENYR
      EMI(I,NT)= EMI(I,NT)/ENYR
      EMIR(I,NT)=EMIR(I,NT)/ENYR
      TIF(I,NT)= TIF(I,NT)/ENYR
      GWIN(I,NT)=GWIN(I,NT)/ENYR
      SWL(I,NT)= SWL(I,NT)/ENYR
      SGW(I,NT)=SGW(I,NT)/ENYR
      DGW(I,NT)=DGW(I,NT)/ENYR
      SSC(I,NT)=SSC(I,NT)/ENYR
      SSW(I,NT)=SSW(I,NT)/ENYR
      SMA(I,NT)=SMA(I,NT)/ENYR
      SMW(I,NT)=SMW(I,NT)/ENYR
      DSC(I,NT)=DSC(I,NT)/ENYR
      DSW(I,NT)=DSW(I,NT)/ENYR
      GWRT(I,NT)=GWRT(I,NT)/ENYR
      SRTF(I,NT)=SRTF(I,NT)/ENYR
      TOF(I,NT)=TOF(I,NT)/ENYR
      GWOF(I,NT)=GWOF(I,NT)/ENYR
      TSWL(I,NT)= TSWL(I,NT)/ENYR
      GWTS(I,NT)= GWTS(I,NT)/ENYR
      IF(NC1.EQ.0) GO TO 210
      DO 205 K=1,NC1
```

Figure G-5. Continued.

```
      PCUU(I,NT,K)= PCUU(I,NT,K)/ENYR
  205 PCU(I,NT,K)= PCU(I,NT,K)/ENYR
  210 IF(NC2.EQ.0) GO TO 225
      DO 220 K=1,NC2
      WLCUU(I,NT,K)= WLCUU(I,NT,K)/ENYR
  220 WLCU(I,NT,K)= WLCU(I,NT,K)/ENYR
      AWLCU(I,NT)=AWLCU(I,NT)/ENYR
      WLSM(I,NT)= WLSM(I,NT)/ENYR
      WLAGW(I,NT)= WLAGW(I,NT)/ENYR
      WLDEF(I,NT)= WLDEF(I,NT)/ENYR
      AWLSM(I,NT)= AWLSM(I,NT)/ENYR
  225 CONTINUE
C
C     ACCUMULATE CORRECTED SUMS OF SQUARES FOR ALL ENTRIES
C
      DO 250 J=1,NYR
      D=ERR1(J)-ERR1(NT)
      ERR1(NSD)=ERR1(NSD)+D*D
      DO 250 I=1,IMT
      IF(NRES.EQ.0) GO TO 670
      D=PRES(I,J)-PRES(I,NT)
      PRES(I,NSD)= PRES(I,NSD)+D*D
      D=WEVAP(I,J)-WEVAP(I,NT)
      WEVAP(I,NSD)=WEVAP(I,NSD)+D*D
      D=EVAP(I,J)-EVAP(I,NT)
      EVAP(I,NSD)= EVAP(I,NSD)+D*D
  670 TOF(I,NSD)=TOF(I,NSD)+(TOF(I,J)-TOF(I,NT))*(TOF(I,J)-TOF(I,NT))
      D=PREC(I,J)-PREC(I,NT)
      PREC(I,NSD)=PREC(I,NSD)+D*D
      D=WLSFC(I,J)-WLSFC(I,NT)
      WLSFC(I,NSD)=WLSFC(I,NSD)+D*D
      D=SIMP(I,J)-SIMP(I,NT)
      SIMP(I,NSD)=SIMP(I,NSD)+D*D
      D=SINT(I,J)-SINT(I,NT)
      SINT(I,NSD)=SINT(I,NSD)+D*D
      D=STIF(I,J)-STIF(I,NT)
      STIF(I,NSD)=STIF(I,NSD)+D*D
      D=TGWA(I,J)-TGWA(I,NT)
      TGWA(I,NSD)=TGWA(I,NSD)+D*D
      D=DELGW(I,J)-DELGW(I,NT)
      DELGW(I,NSD)=DELGW(I,NSD)+D*D
      DUM=GWRT(I,J)-GWRT(I,NT)
      GWRT(I,NSD)=GWRT(I,NSD)+DUM*DUM
      DUM=SRTF(I,J)-SRTF(I,NT)
      SRTF(I,NSD)=SRTF(I,NSD)+DUM*DUM
      DUM=GWOF(I,J)-GWOF(I,NT)
      GWOF(I,NSD)=GWOF(I,NSD)+DUM*DUM
      SGW(I,NSD)=SGW(I,NSD)+(SGW(I,J)-SGW(I,NT))*(SGW(I,J)-SGW(I,NT))
      DGW(I,NSD)=DGW(I,NSD)+(DGW(I,J)-DGW(I,NT))*(DGW(I,J)-DGW(I,NT))
      SSC(I,NSD)=SSC(I,NSD)+(SSC(I,J)-SSC(I,NT))*(SSC(I,J)-SSC(I,NT))
      SSW(I,NSD)=SSW(I,NSD)+(SSW(I,J)-SSW(I,NT))*(SSW(I,J)-SSW(I,NT))
      SMA(I,NSD)=SMA(I,NSD)+(SMA(I,J)-SMA(I,NT))*(SMA(I,J)-SMA(I,NT))
      SMW(I,NSD)=SMW(I,NSD)+(SMW(I,J)-SMW(I,NT))*(SMW(I,J)-SMW(I,NT))
      DSC(I,NSD)=DSC(I,NSD)+(DSC(I,J)-DSC(I,NT))*(DSC(I,J)-DSC(I,NT))
      DSW(I,NSD)=DSW(I,NSD)+(DSW(I,J)-DSW(I,NT))*(DSW(I,J)-DSW(I,NT;)
      RIF(I,NSD)=RIF(I,NSD)+(RIF(I,J)-RIF(I,NT))*(RIF(I,J)-RIF(I,NT))
      CD(I,NSD)=CD(I,NSD)+(CD(I,J)-CD(I,NT))*(CD(I,J)-CD(I,NT))
      PW(I,NSD)=PW(I,NSD)+(PW(I,J)-PW(I,NT))*(PW(I,J)-PW(I,NT))
      PCL(I,NSD)=PCL(I,NSD)+(PCL(I,J)-PCL(I,NT))*(PCL(I,J)-PCL(I,NT))
      SMS(I,NSD)=SMS(I,NSD)+(SMS(I,J)-SMS(I,NT))*(SMS(I,J)-SMS(I,NT))
      ASMS(I,NSD)=ASMS(I,NSD)+(ASMS(I,J)-ASMS(I,NT))*(ASMS(I,J)-
     1ASMS(I,NT))
      RES(I,NSD)=RES(I,NSD)+(RES(I,J)-RES(I,NT))*(RES(I,J)-RES(I,NT))
      DRES(I,NSD)=DRES(I,NSD)+(DRES(I,J)-DRES(I,NT))*(DRES(I,J)-
     1DRES(I,NT))
      TAVE(I,NSD)=TAVE(I,NSD)+(TAVE(I,J)-TAVE(I,NT))*(TAVE(I,J)-
     1TAVE(I,NT))
      F(I,NSD)=F(I,NSD)+(F(I,J)-F(I,NT))*(F(I,J)-F(I,NT))
      USW(I,NSD)=USW(I,NSD)+(USW(I,J)-USW(I,NT))*(USW(I,J)-USW(I,NT))
      DWRZ(I,NSD)=DWRZ(I,NSD)+(DWRZ(I,J)-DWR/(I,NT))*(DWRZ(I,J)-
     1DWRZ(I,NT))
      TSRZ(I,NSD)=TSRZ(I,NSD)+(TSRZ(I,J)-TSRZ(I,NT))*(TSRZ(I,J)-
     1TSRZ(I,NT))
      RTFLO(I,NSD)=RTFLO(I,NSD)+(RTFLO(I,J)-RTFLO(I,NT))*(RTFLO(I,J)-
     1RTFLO(I,NT))
      SOF(I,NSD)=SOF(I,NSD)+(SOF(I,J)-SOF(I,NT))*(SOF(I,J)-SOF(I,NT))
      DEF(I,NSD)=DEF(I,NSD)+(DEF(I,J)-DFF(I,NT))*(DFF(I,J)-DEF(I,NT))
      GFLO(I,NSD)=GFLO(I,NSD)+(GFLO(I,J)-GFLO(I,NT))*(GFLO(I,J)-
     1GFLO(I,NT))
      DCG(I,NSD)=DCG(I,NSD)+(DCG(I,J)-DCG(I,NT))*(DCG(I,J)-DCG(I,NT))
      SPCU(I,NSD)=SPCU(I,NSD)+(SPCU(I,J)-SPCU(I,NT))*(SPCU(I,J)-
     1SPCU(I,NT))
      EXPO(I,NSD)=EXPO(I,NSD)+(EXPO(I,J)-EXPO(I,NT))*(EXPO(I,J)-
     1EXPO(I,NT))
      ACU(I,NSD)=ACU(I,NSD)+(ACU(I,J)-ACU(I,NT))*(ACU(I,J)-ACU(I,NT))
      AGW(I,NSD)=AGW(I,NSD)+(AGW(I,J)-AGW(I,NT))*(AGW(I,J)-AGW(I,NT))
      SWLCU(I,NSD)=SWLCU(I,NSD)+(SWLCU(I,J)-SWLCU(I,NT))*(SWLCU(I,J)-
     1SWLCU(I,NT))
      PWL(I,NSD)=PWL(I,NSD)+(PWL(I,J)-PWL(I,NT))*(PWL(I,J)-PWL(I,NT))
      D=EMID(I,J)-EMID(I,NT)
      EMID(I,NSD)=EMID(I,NSD)+D*D
      EMI(I,NSD)=EMI(I,NSD)+(EMI(I,J)-EMI(I,NT))*(EMI(I,J)-EMI(I,NT))
      D=EMIR(I,J)-EMIR(I,NT)
      EMIR(I,NSD)=EMIR(I,NSD)+D*D
      TIF(I,NSD)=TIF(I,NSD)+(TIF(I,J)-TIF(I,NT))*(TIF(I,J)-TIF(I,NT))
      GWIN(I,NSD)=GWIN(I,NSD)+(GWIN(I,J)-GWIN(I,NT))*(GWIN(I,J)-
     1GWIN(I,NT))
      SWL(I,NSD)=SWL(I,NSD)+(SWL(I,J)-SWL(I,NT))*(SWL(I,J)-SWL(I,NT))
      D=TSWL(I,J)-TSWL(I,NT)
      TSWL(I,NSD)= TSWL(I,NSD)+D*D
      D=GWTS(I,J)-GWTS(I,NT)
      GWTS(I,NSD)= GWTS(I,NSD)+D*D
      IF(NC1.EQ.0) GO TO 235
      DO 230 K=1,NC1
      PCUU(I,NSD,K)=PCUU(I,NSD,K)+(PCUU(I,J,K)-PCUU(I,NT,K))*(PCUU(I,J,K
     1)-PCUU(I,NT,K))
  230 PCU(I,NSD,K)=PCU(I,NSD,K)+(PCU(I,J,K)-PCU(I,NT,K))*(PCU(I,J,K)-
     1PCU(I,NT,K))
  235 IF(NC2.EQ.0) GO TO 250
      DO 240 K=1,NC2
      WLCUU(I,NSD,K)=WLCUU(I,NSD,K)+(WLCUU(I,J,K)-WLCUU(I,NT,K))*(WLCUU(
     1I,J,K)-WLCUU(I,NT,K))
  240 WLCU(I,NSD,K)=WLCU(I,NSD,K)+(WLCU(I,J,K)-WLCU(I,NT,K))*(WLCU(I,J,K
     1)-WLCU(I,NT,K))
      D= AWLCU(I,J)-AWLCU(I,NT)
      AWLCU(I,NSD)= AWLCU(I,NSD)+D*D
      D=WLSM(I,J)-WLSM(I,NT)
      WLSM(I,NSD)= WLSM(I,NSD)+D*D
      D=WLAGW(I,J)-WLAGW(I,NT)
      WLAGW(I,NSG)= WLAGW(I,NSD)+D*D
      D= WLDEF(I,J)-WLDEF(I,NT)
      WLDEF(I,NSD)= WLDEF(I,NSD)+D*D
      D= AWLSM(I,J)- AWLSM(I,NT)
      AWLSM(I,NSD)= AWLSM(I,NSD)+D*D
  250 CONTINUE
C
C     CALCULATE STANDARD DEVIATION FOR ALL ENTRIES
C
      EN1=ENYR-1.
      ERR1(NSD)=SQRT(ERR1(NSD)/EN1)
      DO 275 I=1,IMT
      IF(NRES.EQ.0) GO TO 6/5
      PRES(I,NSD)= SQRT(PRES(I,NSD)/EN1)
      WEVAP(I,NSD)=SQRT(WEVAP(I,NSD)/EN1)
      EVAP(I,NSD)= SQRT(EVAP(I,NSD)/EN1)
  675 SGW(I,NSD)= SQRT(SGW(I,NSD)/EN1)
      PREC(I,NSD)=SQRT(PREC(I,NSD)/EN1)
      WLSFC(I,NSD)=SQRT(WLSFC(I,NSD)/EN1)
      SIMP(I,NSD)=SQRT(SIMP(I,NSD)/EN1)
      SINT(I,NSD)=SQRT(SINT(I,NSD)/EN1)
      STIF(I,NSD)=SQRT(STIF(I,NSD)/EN1)
      TGWA(I,NSD)=SQRT(TGWA(I,NSD)/EN1)
      DELGW(I,NSD)=SQRT(DELGW(I,NSD)/EN1)
      DGW(I,NSD)=SQRT(DGW(I,NSD)/EN1)
      SSC(I,NSD)=SQRT(SSC(I,NSD)/EN1)
      SSW(I,NSD)=SQRT(SSW(I,NSD)/EN1)
      SMA(I,NSD)=SQRT(SMA(I,NSD)/EN1)
      SMW(I,NSD)=SQRT(SMW(I,NSD)/EN1)
      DSC(I,NSD)=SQRT(DSC(I,NSD)/EN1)
      DSW(I,NSD)=SQRT(DSW(I,NSD)/EN1)
      RIF(I,NSD)=SQRT(RIF(I,NSD)/EN1)
      CD(I,NSD)=SQRT(CD(I,NSD)/EN1)
      PW(I,NSD)=SQRT(PW(I,NSD)/EN1)
      PCL(I,NSD)=SQRT(PCL(I,NSD)/EN1)
      SMS(I,NSD)=SQRT(SMS(I,NSD)/EN1;
      ASMS(I,NSD)=SQRT(ASMS(I,NSD)/EN1)
      RES(I,NSD)=SQRT(RES(I,NSD)/EN1)
      DRES(I,NSD)=SQRT(DRES(I,NSD)/EN1)
      TAVE(I,NSD)=SQRT(TAVE(I,NSD)/EN1)
      F(I,NSD)=SQRT(F(I,NSD)/EN1)
      USW(I,NSD)=SQRT(USW(I,NSD)/EN1)
      DWRZ(I,NSD)=SQRT(DWRZ(I,NSD)/EN1)
      TSRZ(I,NSD)=SQRT(TSRZ(I,NSD)/EN1)
      RTFLO(I,NSD)=SQRT(RTFLO(I,NSD)/EN1)
      SOF(I,NSD)=SQRT(SOF(I,NSD)/EN1)
      GFLO(I,NSD)=SQRT(GFLO(I,NSD)/EN1)
      DCG(I,NSD)=SQRT(DCG(I,NSD)/EN1)
      DEF(I,NSD)=SQRT(DEF(I,NSD)/EN1)
      SPCU(I,NSD)=SQRT(SPCU(I,NSD)/EN1)
      EXPO(I,NSD)=SQRT(EXPO(I,NSD)/EN1)
      ACU(I,NSD)=SQRT(ACU(I,NSD)/EN1)
      AGW(I,NSD)=SQRT(AGW(I,NSD)/EN1)
      SWLCU(I,NSD)=SQRT(SWLCU(I,NSD)/EN1)
      PWL(I,NSD)=SQRT(PWL(I,NSD)/EN1)
      EMID(I,NSD)=SQRT(EMID(I,NSD)/EN1)
      EMI(I,NSD)=SQRT(EMI(I,NSD)/EN1)
      EMIR(I,NSD)=SQRT(EMIR(I,NSD)/EN1)
      TIF(I,NSD)=SQRT(TIF(I,NSD)/EN1)
      GWIN(I,NSD)=SQRT(GWIN(I,NSD)/EN1)
      SWL(I,NSD)=SQRT(SWL(I,NSD)/EN1)
      TOF(I,NSD)=SQRT(TOF(I,NSD)/EN1)
      GWRT(I,NSD)=SQRT(GWRT(I,NSD)/EN1)
      SRTF(I,NSD)=SQRT(SRTF(I,NSD)/EN1)
      GWOF(I,NSD)=SQRT(GWOF(I,NSD)/EN1)
      TSWL(I,NSD)= SQRT(TSWL(I,NSD)/EN1)
      GWTS(I,NSD)= SQRT(GWTS(I,NSD)/EN1)
      IF(NC1.EQ.0) GO TO 260
      DO 255 K=1,NC1
      PCUU(I,NSD,K)=SQRT(PCUU(I,NSD,K)/EN1)
  255 PCU(I,NSD,K)=SQRT(PCU(I,NSD,K)/EN1)
  260 IF(NC2.EQ.0) GO TO 275
      DO 270 K=1,NC2
      WLCUU(I,NSD,K)=SQRT(WLCUU(I,NSD,K)/EN1)
  270 WLCU(I,NSD,K)=SQRT(WLCU(I,NSD,K)/EN1)
      AWLCU(I,NSD)= SQRT(AWLCU(I,NSD)/EN1)
      WLSM(I,NSD)= SQRT(WLSM(I,NSD)/EN1)
      WLAGW(I,NSD)= SQRT(WLAGW(I,NSD)/EN1)
      WLDEF(I,NSD)=SQRT(WLDEF(I,NSD)/EN1)
      AWLSM(I,NSD)= SQRT(AWLSM(I,NSD)/EN1)
  275 CONTINUE
      GO TO 100
      END
@I FOR INPUT,INPUT
      SUBROUTINE INPUT(N,NYR,IM,Q,NPR)
      COMMON LYR(35)
      DIMENSION Q(13,32),F(13,32),FMT(18)
      IMT=IM+1
      IF(N.NE.0) READ(5,100) FMT
  100 FORMAT (13A6, A2)
      K=1
      IF (N-1) 5, 10, 15
    5 DO 7 J= 1, NYR
      DO 7 I= 1, IMT
    7 Q(I,J) = 0.
      GO TO 30
   10 L= 1
      GO TO 16
   15 L= 2
   16 DO 18 J=1,NYR
      READ(5,FMT) ID,(Q(I,J) ,I=1,IM)
      Q(IMT,J)=0.
      DO 17 I=1,IM
   17 Q(IMT,J)=Q(IMT,J)+Q(I,J)
      IF(NPR.NE.0)WRITE(6,101)K, ID,LYR(J),(Q(I,J),I=1,IMT)
  101 FORMAT(1XI3,1XA6,1X,A6,5X,13F8.0)
```

Figure G-5. Continued.

```
 10 CONTINUE
    GO TO ( 30, 20) ,L
 20 DO 25 K=2,N
    DO 25 J=1,NYR
    READ (5,FMT) ID,(F(I,J), I=1,IM)
    F(IMT,J)=0.
    DO 21 I=1,IM
 21 F(IMT,J)=F(IMT,J)+F(I,J)
    IF(NPR.NE.0)WRITE(6,101)K,ID,LYR(J),(F(I,J),I=1,IMT)
    DO 25 I= 1,IMT
 25 Q(I,J) = Q(I,J) + F(I,J)
    IF(NPR.NE.0)WRITE(6,102)(LYR(J),(Q(I,J),I=1,IMT),J=1,NYR)
102 FORMAT(1XA6,1X6HTOTALS,12X13F8.0)
 30 RETURN
    END
```

LITTLE BEAR RIVER -- CARD SET-UP FOR SIMULATION RUN

```
AN IOT BUDGET
MEASURED INFLOW          IUNMEASURED INFLOW         I  RESERVOIR STORAGE
CHANGE IN RES STORAGE   0  USEABLE SURFACE WATER      CROPLAND DIVERSIONS
  AMOUNT TO ROOT ZONE       PUMPED WATER               GROUNDWATER INFLOW
CROPLAND PRECIPITATION  I  ROOT ZONE SUPPLY            RZ SUPPLY-P.C.U.
ACCUM SOIL MOISTURE   I-0  CROPLAND P.C.U.             CONS. USE DEFICIT
ACTUAL CROPLAND C.U.    0INPUT PRECIPITATION          CROPLAND RETURN FLOW
M AND I NET USE         0  INTERFLOW SUPPLY TO WL WETLAND PRECIPITATION   I
  POTENTIAL WETLAND CU   EXPORTS                    0  SURFACE OUTFLOW
AVERAGE TEMPERATURE      BLANEY-CRIDDLE "F"            CHANGE IN GW STORAGE
  ACCUM SNOW STORAGE        SNOW MELT               ISNOW STORAGE ADDED       0
  INTERFLOW ADDED        ACCUM INTERFLOW         I-0  INTERFLOW TO GW
OUTFLOW + CHANGE IN GW  M  GAGED SURFACE OUTFLOW      DIFFERENCE (COMP-GAGED)
  GW OUTFLOW                GW RETURN FLOW             SURFACE RETURN FLOW
SNOW STORAGE ADDED      OSNOW MELT                  I  TOTAL GW ADDED
RESERVOIR PRECIPITATION IRESERVOIR EVAPORATION     0  TSWL-WL PCU
ACTUAL WETLAND C.U.     OACCUM WL SOIL MOIST    I-0  WETLAND DEFICIT
  WETLAND ADDITION TO GW   TOTAL SUPPLY TO WL      MEASURED IMPORTS          I
  M AND I DIVERSION         M AND I RETURN FLOW       WETLAND SURFACE OUTFLOW
  UNMEASURED SURFACE IN    GROUNDWATER TO SURFACE   INTERFLOW TO SURFACE
  OCT    NOV   DEC   JAN   FEB   MAR   APR   MAY   JUN   JUL   AUG   SEP ANNUAL
```

GROUP 1 CARDS
OUTPUT LABELS

```
            10-1060  LITTLE BEAR RIVER NEAR PARADISE, UTAH
LBR-2  212 9 9 1 1 1 1 0 1 1 1 0 1 1 1 1 01 50 50 1000 1000 1000 375 100 350 240
LBR-2       3683    1700     1306  1300  400   230    0    1300      200  100    1300
LBR-2     2 1200   350         193        1700         1700
LBR-2 RF COEF   1000 1000 1000 1000 1000 1000 1000  880   880   859   922   897
LBR-2 STFR       102  144  154  161  173  470  447  431   844   489   522   684
LBR-2 SWLR      1000 1000 1000 1000 1000 1000 1000 1000 1000  1000  1000  1000
LBR-2 POH        774  665  642  660  668  828  896 1007 1018  1037   962   842
```

GROUP 2 CARDS
PARAMETER INITIALIZATION
PARADISE SUBAREA

```
LBR-2 AC1    297   188    46   253    33    14    23   146
LBR-2    ALFALF    89    80    65    64    73    97    99   115   119   109   104    98
LBR-2    PASTRE    80    74    58    55    66    81    86   102    99    93    91    87
LBR-2    HAY       85    77    62    60    73    83    94   109   109   101    98    92
LBR-2    GRAIN     22    29    29    29    29    28    74   118   127    73    40    19
LBR-2    CORN      99    29    29    29    29    28    22    60    73    93   106   109
LBR-2    BEETS    102    29    29    29    29    28    22    58    75    96   108   111
LBR 2    TRUCK     22    29    29    29    29    28    22    56    72    83    76    19
LBR-2    UP-IOL    35    30    25    25    25    30    33    38    39    39    39    39
LBR-2 AC2     91   481   293   135
LBR-2    VRDNPH   154   147   131   123   150   167   171   169   164   158   155   154
LBR-2    DNSPHY   137   128   112   101   130   149   156   155   151   144   141   138
LBR-2    MEDPHY   119   110    93    80   110   132   141   141   138   130   126   122
LBR-2    LTPHRY    93    91    77    67   105   120   120   110   103    98    97    95
LBR-2    WATER    137   128   112   101   130   149   156   155   151   144   141   138
LBR-2         1967 1969 MEAN SDEV
(A6,8X12F5.0)
 RIF       1967 1753 1736 1924 1933 1811 4800102802593014660 5280 3798 2424 75629
 RIF       1968 2354 2120 2064 1992 2619 4410 86001670010040 3650 2814 2225
(A6,8X12F5.0)
 CD        1967  30r                                  3516 4990 4823 3156
 CD        1968    0                             533 4872 6008 4560 3660
(A6,8X12F4.2)
LOGUSU     1967  43 131 171 163  74 330 446 195 356  37  11  12
LOGUSU P   1968 190  62 236 134 266 277 200 137 322  11 344  32
(A6,8X12F4.1)
LOGUSU     1967 483 407 228 286 319 385 422 537 607 731 739 639
LOGUSU T   1968 499 396 215 197 294 433 417 543 627 729 661 590
(6XA4,4X12F5.0)
WTRFRMWDIV1967 1537 1498 1537 1537 1388 1537 1785 1845 1785 1845 1845 1785
WTRFRMWDIV1968 1537 1488 1577 1537 1388 1537 1785 1845 1785 1845 1845 1785
(6XA4,4X12F5.0)
WTRFRM MI 1967 -307 -299 -307 -307 -278 -307 -298 -307 -298 -307 -307 -298
WTRFRM MI 1968 -307 -298 -307 -307 -278 -307 -298 -307 -298 -307 -307 -298
(6XA4,4X12F5.0)
LBR-2 TIF 1967 1904 2035 2378 2059 1840 1660 2817 4330 4750 2413 1812 2365
LBR-2 TIF 1968 2556 2485 2551 2122 2661 1532 2356 2769 3253 1668 1646 2172
(A6,8X,12F5.0)
PORRES          1573 2070 2628 3210 3618 5239 97451284012840 9908 5850 3390
PORRES     1968 3818 4139 4477 4737 5312 71421103712440120968 338 5799 4290
(A6,8X12F5.0)
HYRM C     1967                                          2368 3316 2143 1349
HYRM C     1968                                     1711 2805 2661 1404 1101
(A6,8X12F5.0)
101060     1967 2250 2480 2720 2570 2530 5350 89202630016340 3630 3910 3410
101060     1968 3530 3500 3750 3480 4253 5480 69301383C 8480 3000 3630 3150
(6XA4,4X12F5.0)
LBR-2 GWOF1967 1000 1000 1000 1000 1000 1000 1000 1000 1000 1000 1000 1000
LBR-2 GWOF1968 1000 1000 1000 1000 1000 1000 1000 1000 1000 1000 1000 1000
```

GROUP 3 CARDS
INPUT DATA
PARADISE SUBAREA

```
            10-1075  LITTLE BEAR RIVER BELOW PARADISE AT WELLSVILLE, UTAH
LBR-1  212 9 5 1 1 1 1 0 1 1 1 1 1 1 1 1 01 30100 1030 1000 1030 350 100 350 240
LBR-1       9355     1600     3950  4300  500   300    0    3500      500  100    3500
LBR-1     2 1000 1000         372        1600         1600
LBR-1 RF COEF   1000 1000 1000 1000 1000 1000 1000 1000  951   936   940   913
LBR-1 STFR        22   12   40   74   17    9  182  255  939  1000   103   400
LBR-1 SWLR       134   81    0   12  369  211    0  376  647   708   394   267
```

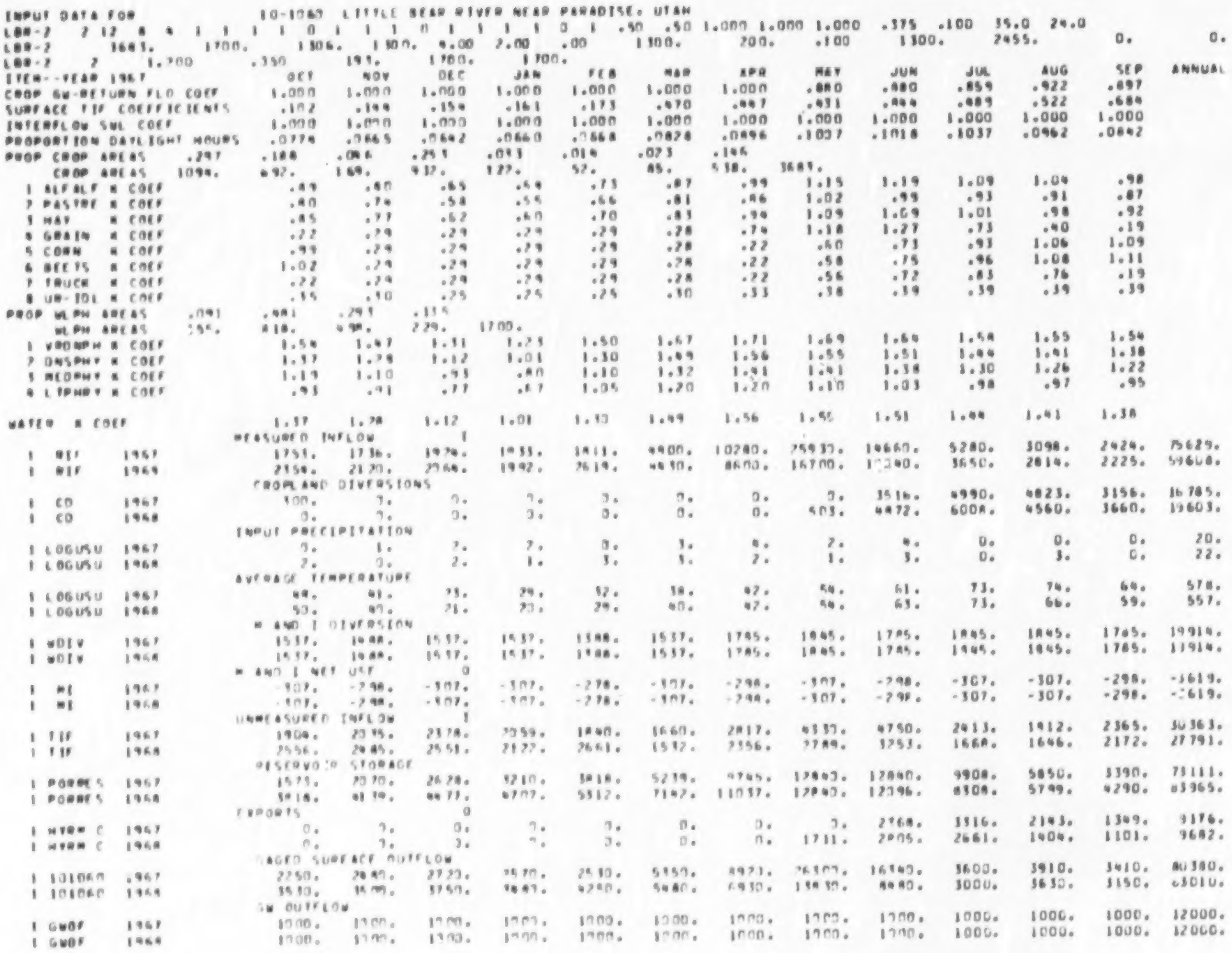
GROUP 2 CARDS
PARAMETER INITIALIZATION
WELLSVILLE SUBAREA

Figure G-5. Continued.

```
LBR-1 POH          774  665  642  660  668  828  896 1037 1018 1037  962  842
LBR-1 PAC1  284   195  023  247  027  010  016  198
LBR-1   ALFALF     99   80   65   64   73   87   99  115  119  109  104   98
LBR-1   PASTRE     80   74   58   55   66   81   96  132   99   93   91   87
LBR-1   HAY        85   77   62   60   73   83   96  139  109  131   98   92
LBR-1   GRAIN      22   29   29   29   29   28   74  118  127   73   40   19
LBR-1   CORN       99   29   29   29   29   28   22   60   73   93  176  109
LBR-1   BEETS     102   29   29   29   29   28   22   58   75   96  108  111
LBR-1   TRUCK      22   29   29   29   29   28   22   56   72   83   76   19
LBR-1   UR-IDL     35   30   25   25   25   30   33   38   39   39   39   39
LBR-1 PAC2  135   221  219  234  191
LBR-1   VRDNPH    154  147  131  123  150  167  171  169  164  158  155  154
LBR-1   DNSPHY    137  128  112  101  130  149  156  155  151  144  141  138
LBR-1   MEDPHY    119  110   93   80  113  132  141  141  138  130  126  122
LBR-1   LTPHRY     93   91   77   67  105  120  120  110  103   98   97   95
LBR-1   VLTPHY     35   30   25   25   25   30   33   38   39   39   39   39
LBR-1   WATER     137  128  112  101  130  149  156  155  151  144  141  138
LBR-1       1967 1968 MEAN SDEV
(A6,8X12F5.0)
101060      1967 2250 2480 2720 2570 2530 5350 89202630016340 3600 3910 3410
101060      1968 3530 3500 3750 3480 4250 5480 693013830 8440 3000 3630 3150
(A6,8X12F5.0)
HYRM C      1967                                              2368 3316 2143 1349
HYRM C      1968                                         1711 2805 2661 1404 1101
(6XA4,4X12F5.0)
LBR-1  CD 1967    0    0    0    0    0    0    0  184 5769 6762 5138 3218
LBR-1  CD 1968  300    0    0    0    0    0    0 2301 6078 5822 3221 2398
(A6,8X12F4.2)
LOGUSU P    1967  43 131 171 163  74 330 446  95 356  37   1  12
LOGUSU P    1968 190  62 236 134 266 277 200 137 322  11 344  32
(A6,8X12F4.1)
LOGUSU T    1967 483 407 228 286 319 385 422 537 607 731 739 639
LOGUSU T    1968 499 396 215 197 294 403 417 563 627 729 661 590
(6XA4,4X12F5.0)
LBR-1 MIDV1967    0    0    0    0    0    0    0    0    0  542    0    0
LBR-1 MIDV1968  300  300  300  300  300  300  300  300  300  300  300  300
(6XA4,4X12F5.0)
LBR-1 MIUS1967 -615 -595 -676 -676 -611 -676 -952 -738 -833 -196 -738 -714
LBR-1 MIUS1966 -315 -295 -315 -376 -311 -561 -295 -315 -295 -315 -315 -295
(6XA4,4X12F5.0)
LBR-1 TIF 1967 2125 1943 1934 2103 1932 2413 1820 1815 1920  338 1310 2327
LBR-1 TIF 1968 2853 2372 2074 2167 2798 2224 1522 1169 1315  234 1190 2136
(A6,8X,12F5.0)
HYRES       1967 5680 826010090103101031014390155701557015420115801014010610
HYRES       196810520105201048010480104801359013500157601467010790 984010180
(4XA6,4X12F5.0)
LB-1 EXPO 1967  648    0    0    0    0    0    0  400  922 3590 2790 1863
LB-1 EXPO 1968    0    0    0    0    0    0    0 2072 1032 3158 1458  991
(A6,8X12F5.0)
101076      1967 1590 1210 2370 3900 3700 2610 99802691016460 1640 2020 2190
101076      1968 4530 4380 4730 4780 5320 4580 7920 9720 7380 1800 3390 3650
(6XA4,4X12F5.0)
LBR-1 GWOF1967 1200 1200 1200 1200 1500 1500 1500 1500 2000 1800 1500 1500
LBR-1 GWOF1968 1500 1400 1300 1250 1500 1500 1500 1500 2000 1800 1500 1500
##
```

GROUP 3 CARDS
INPUT DATA
WELLSVILLE SUBAREA

Figure G-5. Continued.



```
INPUT DATA FOR              10-1060  LITTLE BEAR RIVER NEAR PARADISE, UTAH
LBR-2    2 12  8  4  1  1  1  1  0  1  1  1  0  1  1  1  1  0  1  .50  .50 1.000 1.000 1.000  .375  .100  35.0  24.0
LBR-2        3683.      1700.      1306.   1300.   4.00  2.00   .00      1300.      200.     .100      1300.      2455.        0.        0.
LBR-2    2       1.200        .350        193.      1700.      1700.
ITEM--YEAR 1967                OCT      NOV      DEC      JAN      FEB      MAR      APR      MAY      JUN      JUL      AUG      SEP    ANNUAL
CROP GW-RETURN FLO COEF      1.000    1.000    1.000    1.000    1.000    1.000    1.000     .880     .880     .859     .922     .897
SURFACE TIF COEFFICIENTS      .102     .149     .154     .161     .173     .470     .447     .431     .444     .489     .522     .684
INTERFLOW SUL COEF           1.000    1.000    1.000    1.000    1.000    1.000    1.000    1.000    1.000    1.000    1.000    1.000
PROPORTION DAYLIGHT HOURS    .0774    .0665    .0642    .0660    .0668    .0828    .0896    .1037    .1018    .1037    .0962    .0842
PROP CROP AREAS    .297    .188    .046    .253    .033    .014    .023    .146
     CROP AREAS   1094.    692.    169.    932.    122.     52.     85.    538.   3683.
  1 ALFALF  K COEF              .49      .60      .65      .64      .73      .87      .99     1.15     1.19     1.09     1.04      .98
  2 PASTRE  K COEF              .80      .74      .58      .55      .66      .81      .86     1.02      .99      .93      .91      .87
  3 HAY     K COEF              .85      .77      .62      .60      .70      .83      .94     1.09     1.09     1.01      .98      .92
  4 GRAIN   K COEF              .22      .29      .29      .29      .29      .28      .74     1.18     1.27      .73      .40      .19
  5 CORN    K COEF              .99      .29      .29      .29      .29      .28      .22      .60      .73      .93     1.06     1.09
  6 BEETS   K COEF             1.02      .29      .29      .29      .29      .28      .22      .58      .75      .96     1.08     1.11
  7 TRUCK   K COEF              .22      .29      .29      .29      .29      .28      .22      .56      .72      .83      .76      .19
  8 UR-IDL  K COEF              .15      .10      .25      .25      .25      .30      .33      .38      .39      .39      .39      .39
PROP WLPH AREAS     .091     .481     .293     .135
     WLPH AREAS     155.     818.     498.     229.    1700.
  1 VRDNPH K COEF              1.54     1.47     1.31     1.23     1.50     1.67     1.71     1.69     1.64     1.58     1.55     1.54
  2 DNSPHY K COEF              1.37     1.29     1.12     1.01     1.30     1.49     1.56     1.55     1.51     1.44     1.41     1.38
  3 MEDPHY K COEF              1.19     1.10      .93      .80     1.10     1.32     1.41     1.41     1.38     1.30     1.26     1.22
  4 LTPHRY K COEF               .93      .91      .77      .67     1.05     1.20     1.20     1.10     1.03      .98      .97      .95

WATER  K COEF                  1.37     1.28     1.12     1.01     1.30     1.49     1.56     1.55     1.51     1.44     1.41     1.38
                       MEASURED INFLOW        1
  1   MIF      1967           1751.    1736.    1974.    1933.    1811.    4400.   10280.   25933.   14660.    5280.    3098.    2424.   75629.
  1   MIF      1968           2154.    2120.    2766.    1992.    2619.    4430.    8600.   16700.   10340.    3650.    2814.    2225.   59608.
                         CROPLAND DIVERSIONS
  1   CD       1967            100.       0.       0.       0.       0.       0.       0.       0.    3516.    4990.    4823.    3156.   16785.
  1   CD       1968              0.       0.       0.       0.       0.       0.       0.     503.    4872.    6008.    4560.    3660.   19603.
                       INPUT PRECIPITATION
  1 LOGUSU     1967              0.       1.       2.       2.       0.       3.       4.       2.       4.       0.       0.       0.      20.
  1 LOGUSU     1968              2.       0.       2.       1.       3.       3.       2.       1.       3.       0.       3.       0.      22.
                       AVERAGE TEMPERATURE
  1 LOGUSU     1967             48.      41.      23.      29.      32.      38.      42.      54.      61.      73.      74.      64.     578.
  1 LOGUSU     1968             53.      40.      21.      23.      29.      40.      42.      54.      63.      73.      66.      59.     557.
                         M AND I DIVERSION
  1 WDIV       1967           1537.    1488.    1537.    1537.    1388.    1537.    1785.    1845.    1785.    1845.    1845.    1785.   19914.
  1 WDIV       1968           1537.    1488.    1537.    1537.    1388.    1537.    1785.    1845.    1785.    1845.    1845.    1785.   19914.
                       M AND I NET USE        0
  1   MI       1967           -307.    -298.    -307.    -307.    -278.    -307.    -298.    -307.    -298.    -307.    -307.    -298.   -3619.
  1   MI       1968           -307.    -298.    -307.    -307.    -278.    -307.    -298.    -307.    -298.    -307.    -307.    -298.   -3619.
                       UNMEASURED INFLOW      1
  1 TIF        1967           1904.    2035.    2378.    2059.    1840.    1660.    2817.    4333.    4750.    2413.    1912.    2365.   30363.
  1 TIF        1968           2556.    2485.    2551.    2127.    2661.    1532.    2356.    2789.    3253.    1668.    1646.    2172.   27791.
                         RESERVOIR STORAGE
  1 PORRES     1967           1573.    2070.    2628.    3210.    3818.    5239.    9745.   12843.   12840.    9908.    5850.    3390.   73111.
  1 PORRES     1968           3818.    4139.    4477.    4707.    5512.    7142.   11037.   12840.   12396.    8308.    5799.    4290.   83965.
                       EXPORTS                0
  1 HYRM C     1967              0.       0.       0.       0.       0.       0.       0.       0.    2768.    3316.    2143.    1349.    9176.
  1 HYRM C     1968              0.       0.       0.       0.       0.       0.       0.    1731.    2805.    2661.    1404.    1101.    9682.
                         GAGED SURFACE OUTFLOW
  1 101060     1967           2250.    2480.    2723.    2570.    2530.    5150.    8923.   26307.   16340.    3600.    3910.    3410.   80380.
  1 101060     1968           3530.    3500.    3750.    3483.    4290.    5480.    6930.   13830.    8480.    3000.    3630.    3150.   63010.
                         GW OUTFLOW
  1 GWOF       1967           1000.    1000.    1000.    1000.    1000.    1000.    1000.    1000.    1000.    1000.    1000.    1000.   12000.
  1 GWOF       1968           1000.    1000.    1000.    1000.    1000.    1000.    1000.    1000.    1000.    1000.    1000.    1000.   12000.
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Figure G-6. Sample output for BUDGET.

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                                   10-1060  LITTLE BEAR RIVER NEAR PARADISE, UTAH
ITEM--YEAR 1967                 OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP   ANNUAL
MEASURED INFLOW           I   1753.   1736.   1929.   1933.   1811.   4800.  10280.  25930.  14660.   5280.   3098.   2424.   75629.
UNMEASURED INFLOW         I   1904.   2035.   2378.   2059.   1840.   1660.   2817.   4330.   4750.   2413.   1812.   2365.   30363.
  UNMEASURED SURFACE IN        194.    293.    366.    331.    318.    780.   1259.   1866.   4009.   1180.    946.   1618.   13161.
  GROUNDWATER INFLOW          1710.   1742.   2012.   1728.   1522.    880.   1558.   2464.    741.   1233.    866.    747.   17202.
  RESERVOIR STORAGE           1573.   2070.   2628.   3210.   3818.   5239.   9745.  12840.  12840.   9908.   5850.   3390.    3390.
RESERVOIR PRECIPITATION I        8.     25.     33.     31.     14.     64.     86.     38.     69.      7.      2.      2.     380.
RESERVOIR EVAPORATION     O     41.     22.      8.      9.     13.     27.     39.     83.    110.    167.    155.     95.     772.
CHANGE IN RES STORAGE     O    267.    497.    558.    582.    608.   1421.   4506.   3095.      0.  -2932.  -4058.  -2460.    2084.
  SURFACE RETURN FLOW            0.      0.      0.      0.      0.      0.      0.      0.    316.    528.    282.    244.    1370.
  GROUNDWATER TO SURFACE       561.    666.    865.    789.    613.    849.   1784.    969.   1718.   2040.   1853.   1027.   13734.
  M AND I RETURN FLOW         1844.   1786.   1844.   1844.   1666.   1844.   2083.   2152.   2083.   2152.   2152.   2083.   23533.
  USEABLE SURFACE WATER       5624.   6058.   7094.   7547.   7619.  12128.  20692.  40617.  35585.  23860.  18085.  13153.  198063.
EXPORTS                   O      0.      0.      0.      0.      0.      0.      0.      0.   2368.   3316.   2143.   1349.    9176.
  M AND I DIVERSION           1537.   1488.   1537.   1537.   1388.   1537.   1785.   1845.   1785.   1845.   1845.   1785.   19914.
M AND I NET USE           O   -307.   -298.   -307.   -307.   -278.   -307.   -298.   -307.   -298.   -307.   -307.   -298.   -3619.
  CROPLAND DIVERSIONS          300.      0.      0.      0.      0.      0.      0.      0.   3516.   4990.   4823.   3156.   16785.
  AMOUNT TO ROOT ZONE           75.      0.      0.      0.      0.      0.      0.      0.    879.   1247.   1206.    789.    4196.
  CROPLAND RETURN FLOW         225.      0.      0.      0.      0.      0.      0.      0.   2637.   3742.   3617.   2367.   12589.
CROPLAND PRECIPITATION    I    132.    402.    525.    500.    227.   1013.   1369.    598.   1093.    114.     34.     37.    6043.
SNOW STORAGE ADDED        O      0.      0.    525.    500.    227.      0.      0.      0.      0.      0.      0.      0.    1252.
  ACCUM SNOW STORAGE             0.      0.      0.    525.    554.    164.      0.      0.      0.      0.      0.      0.       0.
  SNOW MELT               I      0.      0.      0.    472.    617.    164.      0.      0.      0.      0.      0.      0.    1252.
  ROOT ZONE SUPPLY             207.    402.      0.    472.    617.   1177.   1369.    598.   1972.   1361.   1240.    826.   10239.
  CROPLAND P.C.U.              367.    178.     62.     78.     99.    201.    362.    999.   1423.   1880.   1580.    860.    8087.
  RZ SUPPLY-P.C.U.            -160.    224.    -62.    393.    518.    976.   1007.   -400.    549.   -519.   -340.    -34.    2152.
ACCUM SOIL MOISTURE     I-O   1300.   1140.   1364.   1302.   1695.   2213.   2455.   2455.   2055.   2455.   1937.   1596.    1562.
  CONS. USE DEFICIT              0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.       0.
ACTUAL CROPLAND C.U.      O    367.    178.     62.     78.     99.    201.    362.    999.   1423.   1880.   1580.    860.    8087.
  INTERFLOW ADDED                0.      0.      0.      0.      0.    734.   1007.      0.    149.      0.      0.      0.    1890.
  GW RETURN FLOW               225.      0.      0.      0.      0.      0.      0.      0.   2321.   3215.   3335.   2123.   11219.
ACCUM INTERFLOW         I-O   1300.   1300.   1300.   1300.   1300.   1300.   1300.   1300.   1300.   1300.   1300.   1300.    1300.
  INTERFLOW TO SURFACE           0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.       0.
  INTERFLOW SUPPLY TO WL      1447.   1254.   1574.   1240.   1034.   1126.   2077.   1976.   2723.   3960.   3714.   2383.    4460.
WETLAND PRECIPITATION     I     61.    186.    242.    231.    105.    467.    632.    276.    504.     52.     16.     17.    2789.
SNOW STORAGE ADDED        O      0.      0.    242.    231.    105.      0.      0.      0.      0.      0.      0.      0.     578.
  ACCUM SNOW STORAGE             0.      0.      0.    242.    256.     76.      0.      0.      0.      0.      0.      0.       0.
SNOW MELT                 I      0.      0.      0.    218.    285.     76.      0.      0.      0.      0.      0.      0.     578.
  TOTAL SUPPLY TO WL          1508.   1440.   1524.   1458.   1319.   1669.   2709.   2253.   3227.   4013.   3729.   2400.   27249.
  POTENTIAL WETLAND CU         352.    179.     64.     74.    111.    225.    330.    688.    914.   1378.   1282.    778.    6375.
  TSWL-WL PCU                 1156.   1261.   1460.   1384.   1208.   1444.   2379.   1564.   2313.   2635.   2448.   1622.   20874.
ACCUM WL SOIL MOIST     I-O   1700.   1700.   1700.   1700.   1700.   1700.   1700.   1700.   1700.   1700.   1700.   1700.    1700.
  WETLAND DEFICIT                0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.       0.
ACTUAL WETLAND C.U.       O    352.    179.     64.     74.    111.    225.    330.    688.    914.   1378.   1282.    778.    6375.
  WETLAND SURFACE OUTFLOW      561.    666.    865.    789.    613.    849.   1784.    969.   1718.   2040.   1853.   1027.   13734.
  WETLAND ADDITION TO GW       595.    595.    595.    595.    595.    595.    595.    595.    595.    595.    595.    595.    7140.
  INTERFLOW TO GW              487.    487.    487.    487.    487.    487.    487.    487.    487.    487.    487.    487.    5850.
  TOTAL GW ADDED              1082.   1082.   1082.   1082.   1082.   1082.   1082.   1082.   1082.   1082.   1082.   1082.   12990.
OUTFLOW + CHANGE IN GW  R     3297.   3582.   4012.   3883.   3496.   6435.  10244.  27015.  16158.   4883.   4507.   4556.   92067.
  GW OUTFLOW                  1000.   1000.   1000.   1000.   1000.   1000.   1000.   1000.   1000.   1000.   1000.   1000.   12000.
  CHANGE IN GW STORAGE          82.     82.     82.     82.     82.     82.     82.     82.     82.     82.     82.     82.     990.
  SURFACE OUTFLOW             2214.   2500.   2929.   2800.   2413.   5352.   9162.  25932.  15076.   3801.   3424.   3473.   79077.
  GAGED SURFACE OUTFLOW       2250.   2480.   2720.   2570.   2530.   5350.   8920.  26300.  16340.   3600.   3910.   3410.   80380.
  DIFFERENCE (COMP-GAGED)      -36.     20.    209.    230.   -117.      2.    242.   -368.  -1264.    201.   -486.     63.   -1303.
SUM OF ABSOLUTE DIFFERENCES =          3238.


                                                    CONSUMPTIVE USE CALCULATIONS
        YEAR 1967               OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP   ANNUAL
INPUT PRECIPITATION             .43    1.31    1.71    1.63     .74    3.30    4.46    1.95    3.56     .37     .11     .12    19.69
AVERAGE TEMPERATURE           48.30   40.70   22.80   28.60   31.90   38.50   42.20   53.70   60.70   73.10   73.90   63.90    48.19
BLANEY-CRIDDLE "F"             3.74    2.71    1.46    1.89    2.13    3.19    3.78    5.41    6.18    7.58    7.11    5.38    50.55
AGRICULTURAL CROPS
 1 ALFALF UNIT USE (IN.)       1.74     .84     .29     .36     .47     .98    1.56    3.82    5.41    7.85    7.13    4.17    34.62
 1 ALFALF USE (ACRE-FT)        158.     77.     26.     33.     43.     89.    142.    349.    493.    716.    650.    380.    3156.
 2 PASTRE UNIT USE (IN.)       1.56     .78     .25     .31     .42     .91    1.35    3.39    4.50    6.70    6.24    3.70    30.13
 2 PASTRE USE (ACRE-FT)         90.     45.     15.     18.     24.     52.     78.    196.    260.    387.    360.    214.    1739.
 3 HAY    UNIT USE (IN.)       1.66     .81     .27     .34     .45     .93    1.48    3.63    4.96    7.28    6.72    3.92    32.44
 3 HAY    USE (ACRE-FT)         23.     11.      4.      5.      6.     13.     21.     51.     70.    103.     95.     55.     458.
 4 GRAIN  UNIT USE (IN.)        .43     .31     .13     .16     .19     .31    1.16    3.92    7.78    5.26    2.74     .81    21.20
 4 GRAIN  USE (ACRE-FT)         33.     24.     10.     13.     14.     24.     90.    307.    449.    408.    213.     63.    1646.
 5 CORN   UNIT USE (IN.)       1.93     .31     .13     .16     .19     .31     .35    2.30    3.32    6.70    7.27    4.64    27.30
 5 CORN   USE (ACRE-FT)         20.      3.      1.      2.      2.      3.      4.     23.     34.     68.     74.     47.     277.
 6 BEETS  UNIT USE (IN.)       1.99     .31     .13     .16     .19     .31     .35    1.93    3.41    6.92    7.41    4.73    27.82
 6 BEETS  USE (ACRE-FT)          9.      1.      0.      0.      0.      1.      1.      8.     15.     30.     32.     20.     120.
 7 TRUCK  UNIT USE (IN.)        .43     .31     .13     .16     .19     .31     .35    1.86    3.28    5.98    5.21     .81    19.01
 7 TRUCK  USE (ACRE-FT)          3.      2.      0.      1.      1.      2.      2.     13.     23.     42.     37.      6.     134.
 8 UR-IDL UNIT USE (IN.)        .68     .32     .11     .14     .16     .34     .52    1.26    1.77    2.81    2.67    1.66    12.45
 8 UR-IDL USE (ACRE-FT)         31.     14.      5.      6.      7.     15.     23.     57.     79.    126.    120.     74.     558.
  CROPLAND P.C.U.              367.    179.     62.     78.     99.    201.    362.    999.   1423.   1880.   1580.    860.    8087.
ACTUAL CROPLAND C.U.      O    367.    178.     62.     78.     99.    201.    362.    999.   1423.   1880.   1580.    860.    8087.
WET LAND PHREATOPHYTES
 1 VRDNPH UNIT USE (IN.)       3.00    1.55     .58     .70     .96    1.87    2.69    5.62    7.46   11.39   10.63    6.56    53.00
 1 VRDNPH USE (ACRE-FT)         39.     20.      7.      9.     12.     24.     35.     72.     96.    147.    137.     85.     683.
 2 DNSPHY UNIT USE (IN.)       2.67    1.35     .49     .57     .83    1.67    2.45    5.15    6.87   10.38    9.67    5.88    47.99
 2 DNSPHY USE (ACRE-FT)        182.     92.     34.     39.     57.    114.    167.    351.    468.    707.    659.    400.    3270.
 3 MEDPHY UNIT USE (IN.)       2.32    1.16     .41     .45     .70    1.48    2.22    4.69    6.28    9.37    8.64    5.20    42.92
 3 MEDPHY USE (ACRE-FT)         96.     48.     17.     19.     29.     61.     92.    195.    261.    389.    359.    216.    1781.
 4 LTPHRY UNIT USE (IN.)       1.81     .96     .34     .38     .67    1.35    1.89    3.66    4.69    7.06    6.65    4.05    33.50
 4 LTPHRY USE (ACRE-FT)         35.     18.      6.      7.     13.     26.     36.     73.     90.    135.    127.     77.     641.
  POTENTIAL WETLAND CU         352.    179.     64.     74.    111.    225.    330.    688.    914.   1378.   1282.    778.    6375.
ACTUAL WETLAND C.U.       O    352.    179.     64.     74.    111.    225.    330.    688.    914.   1379.   1282.    778.    6375.
RESERVOIR EVAPORATION     O    2.67    1.35     .49     .57     .83    1.67    2.45    5.15    6.87   10.38    9.67    5.88    47.99
RESERVOIR EVAPORATION     O     43.     22.      8.      9.     13.     27.     39.     83.    113.    167.    155.     95.     772.

                        1967  FLOW VALUES IN CFS FOR WATER QUALITY MODEL
OI     1967            29.51   29.17   31.29   31.44   32.61   78.06  172.76  421.71  246.37   85.87   50.38   40.74  104.46
OS     1967             3.16    4.92    5.96    5.39    5.73   12.69   21.16   30.35   67.37   19.19   15.39   27.19   18.18
OGI    1967             9.13   11.27   14.07   12.83   11.03   13.81   29.98   15.76   28.87   33.18   30.13   17.26   18.97
OD     1967            29.98   25.01   25.03   25.09   24.99   25.09   30.09   30.01  128.88  165.09  143.30  105.71   63.37
OIR    1967              .00     .03     .03     .03     .03     .09     .00     .30    5.32    8.56    4.59    4.10    1.89
OEF    1967            29.99   30.01   29.99   29.99   30.09   29.99   35.01   35.00   35.01   35.00   35.00   35.01   32.51
OO     1967            36.01   42.01   47.64   45.54   43.45   87.04  153.97  421.75  253.35   61.92   55.69   58.37  109.23
OGFLO  1967            36.59   41.68   44.24   41.83   45.56   87.01  149.91  427.73  274.60   58.55   63.59   57.31  111.03
ODIFF  1967             -.59     .34    3.40    3.75   -2.11     .03    4.06   -5.98  -21.25    3.27   -7.90    1.06   -1.80
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Figure G-6. Continued.

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                                            10-1060  LITTLE BEAR RIVER NEAR PARADISE, UTAH
ITEM--YEAR 1969                    OCT      NOV      DEC      JAN      FEB      MAR      APR      MAY      JUN      JUL      AUG      SEP   ANNUAL
MEASURED INFLOW              I   2354.    2120.    2064.    1992.    2619.    4430.    8600.   16700.   10040.    3650.    2814.    2225.   59608.
UNMEASURED INFLOW            I   2556.    2485.    2551.    2122.    2661.    1532.    2356.    2789.    3253.    1668.    1646.    2172.   27791.
  UNMEASURED SURFACE IN           261.     358.     393.     342.     460.     720.    1053.    1202.    2746.     816.     859.    1486.   10695.
  GROUNDWATER INFLOW             2295.    2127.    2158.    1780.    2201.     812.    1303.    1587.     507.     852.     787.     686.   17096.
  RESERVOIR STORAGE              3818.    4139.    4477.    4707.    5312.    7142.   11037.   12840.   12096.    8308.    5799.    4290.    4290.
RESERVOIR PRECIPITATION I          37.      12.      46.      26.      51.      53.      39.      26.      62.       2.      66.       6.     427.
RESERVOIR EVAPORATION        O     47.      20.       7.       6.      12.      31.      38.      85.     119.     166.     120.      78.     730.
CHANGE IN RES STORAGE        O    428.     321.     338.     230.     605.    1830.    3895.    1803.    -744.   -3788.   -2509.   -1509.     900.
  SURFACE RETURN FLOW               0.       0.       0.       0.       0.       0.       0.      45.     438.     635.     267.     283.    1669.
  GROUNDWATER TO SURFACE         1099.     967.    1015.     647.    1670.    1799.     448.     323.    2295.    2287.    3007.    1774.   17331.
  M AND I RETURN FLOW            1844.    1786.    1844.    1844.    1666.    1844.    2083.    2152.    2083.    2152.    2152.    2083.   23533.
  USEABLE SURFACE WATER          8938.    9041.    9493.    9371.   11161.   14128.   19326.   31900.   30385.   21472.   17354.   13578.  195597.
EXPORTS                      O      0.       0.       0.       0.       0.       0.       0.    1711.    2805.    2661.    1404.    1101.    9682.
  M AND I DIVERSION              1537.    1488.    1537.    1537.    1388.    1537.    1785.    1845.    1785.    1845.    1845.    1785.   19914.
M AND I NET USE              O   -307.    -298.    -307.    -307.    -278.    -307.    -298.    -307.    -298.    -307.    -307.    -298.   -3619.
  CROPLAND DIVERSIONS               0.       0.       0.       0.       0.       0.       0.     503.    4872.    6008.    4560.    3660.   19603.
  AMOUNT TO ROOT ZONE               0.       0.       0.       0.       0.       0.       0.     176.    1218.    1502.    1140.     915.    4901.
  CROPLAND RETURN FLOW              0.       0.       0.       0.       0.       0.       0.     377.    3654.    4506.    3420.    2745.   14702.
CROPLAND PRECIPITATION       I    583.     190.     724.     411.     816.     650.     614.     423.     988.      34.    1056.      98.    6786.
SNOW STORAGE ADDED           O      0.       0.     724.     411.     816.       0.       0.       0.       0.       0.       0.       0.    1952.
  ACCUM SNOW STORAGE                0.       0.       0.     724.    1136.     898.       0.       0.       0.       0.       0.       0.       0.
  SNOW MELT                  I      0.       0.       0.       0.    1054.     898.       0.       0.       0.       0.       0.       0.    1952.
  ROOT ZONE SUPPLY                583.     190.       0.       0.    1054.    1748.     614.     546.    2206.    1536.    2196.    1013.   11687.
  CROPLAND P.C.U.                 399.     165.      59.      54.      91.     229.     350.    1027.    1539.    1868.    1215.     709.    7704.
  RZ SUPPLY-P.C.U.                184.      25.     -59.     -54.     963.    1519.     264.    -481.     668.    -332.     980.     304.    3983.
ACCUM SOIL MOISTURE        I-O   1562.    1747.    1772.    1718.    1660.    2455.    2455.    2455.    1975.    2455.    2123.    2455.    2455.
  CONS. USE DEFICIT                 0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
ACTUAL CROPLAND C.U.         O    399.     165.      59.      54.      91.     229.     350.    1027.    1539.    1868.    1215.     709.    7704.
  INTERFLOW ADDED                   0.       0.       0.       0.     167.    1519.     264.       0.     187.       0.     648.     304.    3090.
  GW RETURN FLOW                    0.       0.       0.       0.       0.       0.       0.     332.    3216.    3871.    3153.    2462.   13034.
ACCUM INTERFLOW            I-O   1300.    1300.    1300.    1300.    1300.    1300.    1300.    1300.    1300.    1300.    1300.    1300.    1300.
  INTERFLOW TO SURFACE              0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
  INTERFLOW SUPPLY TO WL         1808.    1640.    1671.    1293.    1880.    1844.    1079.    1431.    3423.    4236.    4101.    2966.   27370.
WETLAND PRECIPITATION        I    269.      84.     334.     190.     377.     392.     283.     194.     456.      16.     487.      45.    3132.
SNOW STORAGE ADDED           O      0.       0.     334.     190.     377.       0.       0.       0.       0.       0.       0.       0.     901.
  ACCUM SNOW STORAGE                0.       0.       0.     334.     524.     414.       0.       0.       0.       0.       0.       0.       0.
SNOW MELT                    I      0.       0.       0.       0.     487.     414.       0.       0.       0.       0.       0.       0.     901.
  TOTAL SUPPLY TO WL             2077.    1727.    1671.    1293.    2367.    2651.    1362.    1626.    3879.    4251.    4588.    3011.   30502.
  POTENTIAL WETLAND CU            383.     165.      61.      51.     102.     257.     319.     708.     989.    1369.     986.     641.    6031.
  TSWL-WL PCU                    1694.    1562.    1610.    1242.    2265.    2394.    1043.     918.    2890.    2882.    3602.    2369.   24471.
ACCUM WL SOIL MOIST        I-O   1700.    1700.    1700.    1700.    1700.    1700.    1700.    1700.    1700.    1700.    1700.    1700.    1700.
  WETLAND DEFICIT                   0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
ACTUAL WETLAND C.U.          O    383.     165.      61.      51.     102.     257.     319.     708.     989.    1369.     986.     641.    6031.
  WETLAND SURFACE OUTFLOW        1099.     967.    1015.     647.    1670.    1799.     448.     323.    2295.    2287.    3007.    1774.   17331.
  WETLAND ADDITION TO GW          595.     595.     595.     595.     595.     595.     595.     595.     595.     595.     595.     595.    7140.
  INTERFLOW TO GW                 487.     487.     487.     487.     487.     487.     487.     487.     487.     487.     487.     487.    5850.
  TOTAL GW ADDED                 1082.    1082.    1082.    1082.    1082.    1082.    1082.    1082.    1082.    1082.    1082.    1082.   12990.
OUTFLOW + CHANGE IN GW       O   4665.    4496.    4561.    4163.    5544.    6531.    7587.   15584.    9909.    3733.    4829.    3825.   75423.
  GW OUTFLOW                     1000.    1000.    1000.    1000.    1000.    1000.    1000.    1000.    1000.    1000.    1000.    1000.   12000.
  CHANGE IN GW STORAGE             82.      82.      82.      82.      82.      82.      82.      82.      82.      82.      82.      82.     990.
  SURFACE OUTFLOW                3583.    3414.    3479.    3077.    4461.    5449.    6504.   14501.    8827.    2650.    3746.    2742.   62433.
  GAGED SURFACE OUTFLOW          3530.    3500.    3750.    3480.    4250.    5480.    6930.   13830.    8480.    3000.    3630.    3150.   63010.
  DIFFERENCE (COMP-GAGED)          53.     -86.    -271.    -403.     211.     -31.    -426.     671.     347.    -350.     116.    -408.    -577.
SUM OF ABSOLUTE DIFFERENCES =             3373.

                                                       CONSUMPTIVE USE CALCULATIONS
        YEAR 1969                  OCT      NOV      DEC      JAN      FEB      MAR      APR      MAY      JUN      JUL      AUG      SEP   ANNUAL
INPUT PRECIPITATION               1.90      .62     2.16     1.54     2.66     2.77     2.00     1.37     3.22      .11     3.44      .32    22.11
AVERAGE TEMPERATURE              49.90    39.60    21.50    19.70    29.40    40.30    41.70    56.30    62.70    72.90    66.10    59.00    46.42
BLANEY-CRIDDLE "F"                3.86     2.63     1.18     1.10     1.96     3.34     3.74     5.47     6.38     7.56     6.36     4.97    48.55
AGRICULTURAL CROPS
 1 ALFALF UNIT USE (IN.)          1.89      .74      .27      .25      .43     1.11     1.51     3.93     5.85     7.80     5.49     3.44    32.76
 1 ALFALF USE (ACRE-FT)           172.      71.      25.      23.      39.     101.     137.     358.     534.     711.     500.     314.    2986.
 2 PASTRE UNIT USE (IN.)          1.70      .72      .24      .21      .39     1.04     1.31     3.49     4.87     6.66     4.80     3.05    28.48
 2 PASTRE USE (ACRE-FT)            98.      42.      14.      12.      22.      60.      76.     201.     281.     384.     277.     176.    1643.
 3 HAY    UNIT USE (IN.)          1.40      .75      .26      .23      .41     1.06     1.43     3.73     5.36     7.23     5.17     3.23    30.67
 3 HAY    USE (ACRE-FT)            25.      11.       4.       3.       6.      15.      20.      53.      76.     102.      73.      46.     433.
 4 GRAIN  UNIT USE (IN.)           .47      .28      .12      .11      .17      .36     1.13     4.04     6.25     5.23     2.11      .67    20.93
 4 GRAIN  USE (ACRE-FT)            36.      22.       9.       9.      13.      28.      87.     313.     485.     406.     164.      52.    1625.
 5 CORN   UNIT USE (IN.)          2.10      .28      .12      .11      .17      .36      .33     2.05     3.59     6.66     5.59     3.83    25.20
 5 CORN   USE (ACRE-FT)            21.       3.       1.       1.       2.       4.       3.      21.      36.      67.      57.      39.     255.
 6 BEETS  UNIT USE (IN.)          2.16      .28      .12      .11      .17      .36      .33     1.98     3.69     6.87     5.70     3.90    25.68
 6 BEETS  USE (ACRE-FT)             9.       1.       0.       0.       0.       2.       1.       9.      16.      30.      24.      17.     110.
 7 TRUCK  UNIT USE (IN.)           .47      .28      .12      .11      .17      .36      .33     1.91     3.54     5.94     4.01      .67    17.92
 7 TRUCK  USE (ACRE-FT)             3.       2.       0.       0.       1.       1.       2.      14.      25.      42.      28.       5.     127.
 8 UR-IDL UNIT USE (IN.)           .74      .29      .10      .10      .15      .38      .50     1.30     1.92     2.79     2.06     1.37    11.71
 8 UR-IDL USE (ACRE-FT)            33.      13.       5.       4.       7.      17.      23.      58.      86.     125.      92.      61.     525.
  CROPLAND P.C.U.                 399.     165.      59.      54.      91.     229.     350.    1027.    1539.    1868.    1215.     709.    7704.
ACTUAL CROPLAND C.U.         O    399.     165.      59.      54.      91.     229.     350.    1027.    1539.    1868.    1215.     709.    7704.
WET LAND PHREATOPHYTES
 1 WRDNPH UNIT USE (IN.)          3.27     1.44      .54      .48      .88     2.14     2.60     5.78     8.07    11.31     8.18     5.41    50.09
 1 WRDNPH USE (ACRE-FT)            42.      19.       7.       6.      11.      28.      34.      75.     104.     146.     105.      70.     646.
 2 DNSPHY UNIT USE (IN.)          2.91     1.25      .46      .39      .77     1.91     2.37     5.30     7.43    10.31     7.44     4.84    45.38
 2 DNSPHY USE (ACRE-FT)           198.      85.      32.      27.      52.     130.     162.     361.     506.     703.     507.     330.    3092.
 3 MEDPHY UNIT USE (IN.)          2.52     1.37      .13      .31      .65     1.69     2.15     4.82     6.79     9.31     6.65     4.28    40.63
 3 MEDPHY USE (ACRE-FT)           105.      45.      16.      13.      27.      70.      89.     203.     282.     386.     276.     178.    1686.
 4 LTPHRY UNIT USE (IN.)          1.97      .99      .32      .26      .62     1.53     1.83     3.76     5.37     7.02     5.12     3.34    31.72
 4 LTPHRY USE (ACRE-FT)            38.      17.       6.       5.      12.      29.      35.      72.      97.     134.      98.      64.     607.
  POTENTIAL WETLAND CU            383.     165.      61.      51.     102.     257.     319.     708.     989.    1369.     986.     641.    6031.
ACTUAL WETLAND C.U.          O    383.     165.      61.      51.     102.     257.     319.     708.     989.    1369.     986.     641.    6031.
RESERVOIR EVAPORATION        O    2.91     1.25      .46      .39      .77     1.91     2.37     5.30     7.43    10.31     7.44     4.84    45.38
RESERVOIR EVAPORATION        O     47.      20.       7.       6.      12.      31.      38.      85.     119.     166.     120.      78.     730.

                              1969  FLOW VALUES IN CFS FOR WATER QUALITY MODEL
QI      1969                 38.28    35.61    33.57    32.40    47.16    72.05   144.53   271.60   168.77    59.36    45.77    37.39    82.34
QS      1969                  4.24     6.01     6.39     5.56     8.29    11.71    17.70    19.55    46.14    13.27    13.97    24.97    14.77
QGI     1969                 17.48    16.25    16.51    10.52    30.06    29.26     7.53     5.25    38.57    37.20    48.91    29.82    23.96
QD      1969                 25.00    25.01    25.00    25.00    24.99    25.00    30.00    66.01   159.01   170.95   127.00   110.01    67.96
QIR     1969                   .00      .00      .00      .00      .00      .00      .00      .74     7.37    10.33     4.34     4.75     2.30
QFF     1969                 29.99    30.01    29.99    29.99    30.00    29.99    35.01    35.00    35.01    35.00    35.00    35.01    32.51
QO      1969                 58.27    57.37    56.58    50.08    80.32    88.61   109.31   235.84   148.34    43.10    60.92    46.38    86.24
QGFLO   1969                 57.41    58.82    60.99    56.63    76.53    89.17   116.46   224.92   142.51    48.79    59.04    52.94    87.03
QDIFF   1969                   .86    -1.45    -4.41    -6.55     3.83     -.51    -7.15    10.92     5.82    -5.69     1.89    -6.86     -.80
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Figure G-6. Continued.

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                              10-1060  LITTLE BEAR RIVER NEAR PARADISE, UTAH
ITEM--YEAR MEAN                   OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP   ANNUAL
MEASURED INFLOW              I  2053.   1978.   1999.   1962.   2215.   4615.   9440.  21315.  12350.   4465.   2956.   2324.   67618.
UNMEASURED INFLOW            I  2230.   2260.   2464.   2090.   2250.   1596.   2586.   3559.   4001.   2040.   1729.   2268.   29077.
  UNMEASURED SURFACE IN          227.    325.    380.    337.    389.    750.   1156.   1534.   3377.    998.    903.   1552.   11928.
  GROUNDWATER INFLOW            2003.   1935.   2085.   1754.   1861.    846.   1430.   2025.    624.   1043.    826.    717.   17149.
  RESERVOIR STORAGE             2695.   3104.   3552.   3958.   4565.   6190.  10391.  12880.  12468.   9108.   5824.   3840.    3840.
RESERVOIR PRECIPITATION I         22.     19.     39.     29.     33.     59.     62.     32.     65.      5.     34.      4.     403.
RESERVOIR EVAPORATION   O         45.     21.      8.      8.     13.     29.     39.     84.    115.    166.    138.     86.     751.
CHANGE IN RES STORAGE   O        347.    409.    448.    406.    606.   1625.   4200.   2489.   -372.  -3360.  -3283.  -1984.    1492.
  SURFACE RETURN FLOW              0.      0.      0.      0.      0.      0.      0.     23.    377.    582.    274.    263.    1519.
  GROUNDWATER TO SURFACE         830.    817.    940.    718.   1141.   1324.   1116.    646.   2006.   2164.   2430.   1401.   15533.
  M AND I RETURN FLOW           1844.   1786.   1844.   1844.   1666.   1844.   2083.   2152.   2083.   2152.   2152.   2083.   23533.
  USEABLE SURFACE WATER         7281.   7549.   8294.   8434.   9390.  13128.  20009.  36309.  32945.  22666.  17720.  13366.  196830.
EXPORTS                 O          0.      0.      0.      0.      0.      0.      0.    855.   2586.   2988.   1773.   1225.    9429.
  M AND I DIVERSION             1537.   1488.   1537.   1537.   1388.   1537.   1785.   1845.   1785.   1845.   1845.   1785.   19914.
M AND I NET USE         O       -307.   -298.   -307.   -307.   -278.   -307.   -298.   -307.   -298.   -307.   -307.   -298.   -3619.
  CROPLAND DIVERSIONS            150.      0.      0.      0.      0.      0.      0.    251.   4194.   5699.   4691.   3408.   18194.
  AMOUNT TO ROOT ZONE             38.      0.      0.      0.      0.      0.      0.     63.   1048.   1375.   1173.    852.    4548.
  CROPLAND RETURN FLOW           112.      0.      0.      0.      0.      0.      0.    189.   3145.   4124.   3519.   2556.   13645.
CROPLAND PRECIPITATION  I        358.    296.    625.    456.    522.    971.    991.    509.   1040.     74.    545.     68.    6415.
SNOW STORAGE ADDED      O          0.      0.    625.    456.    522.      0.      0.      0.      0.      0.      0.      0.    1602.
  ACCUM SNOW STORAGE               0.      0.      0.    625.    845.    531.      0.      0.      0.      0.      0.      0.       0.
  SNOW MELT             I          0.      0.      0.    236.    835.    531.      0.      0.      0.      0.      0.      0.    1602.
  ROOT ZONE SUPPLY               395.    296.      0.    236.    835.   1462.    991.    572.   2089.   1448.   1718.    920.   10963.
  CROPLAND P.C.U.                383.    171.     60.     66.     95.    215.    356.   1013.   1481.   1874.   1398.    784.    7896.
  RZ SUPPLY-P.C.U.                12.    125.    -60.    170.    741.   1248.    635.   -440.    608.   -425.    320.    135.    3067.
ACCUM SOIL MOISTURE   I-O       1431.   1644.   1568.   1508.   1677.   2334.   2455.   2455.   2715.   2455.   2030.   2026.    2009.
  CONS. USE DEFICIT                0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.       0.
ACTUAL CROPLAND C.U.    O        383.    171.     60.     66.     95.    215.    356.   1013.   1481.   1874.   1398.    784.    7896.
  INTERFLOW ADDED                  0.      0.      0.      0.     84.   1127.    635.      0.    168.      0.    324.    152.    2490.
  GW RETURN FLOW                 112.      0.      0.      0.      0.      0.      0.    166.   2768.   3543.   3244.   2293.   12126.
ACCUM INTERFLOW       I-O       1300.   1300.   1300.   1300.   1300.   1300.   1300.   1300.   1300.   1300.   1300.   1300.    1300.
  INTERFLOW TO SURFACE             0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.       0.
  INTERFLOW SUPPLY TO WL        1628.   1447.   1597.   1266.   1457.   1485.   1578.   1704.   3073.   4098.   3907.   2674.   25915.
WETLAND PRECIPITATION   I        165.    137.    288.    210.    241.    430.    458.    235.    480.     34.    251.     31.    2961.
SNOW STORAGE ADDED      O          0.      0.    288.    210.    241.      0.      0.      0.      0.      0.      0.      0.     739.
  ACCUM SNOW STORAGE               0.      0.      0.    288.    390.    245.      0.      0.      0.      0.      0.      0.       0.
SNOW MELT               I          0.      0.      0.    109.    386.    245.      0.      0.      0.      0.      0.      0.     739.
  TOTAL SUPPLY TO WL            1793.   1584.   1597.   1375.   1843.   2160.   2036.   1939.   3553.   4132.   4159.   2705.   28876.
  POTENTIAL WETLAND CU           367.    172.     63.     62.    107.    241.    325.    698.    952.   1373.   1134.    710.    6203.
  TSWL-WL PCU                   1426.   1412.   1535.   1313.   1736.   1919.   1711.   1241.   2601.   2759.   3025.   1996.   22673.
ACCUM WL SOIL MOIST   I-O       1700.   1700.   1700.   1700.   1700.   1700.   1700.   1700.   1700.   1700.   1700.   1700.    1700.
  WETLAND DEFICIT                  0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.       0.
ACTUAL WETLAND C.U.     O        367.    172.     63.     62.    107.    241.    325.    698.    952.   1373.   1134.    710.    6203.
  WETLAND SURFACE OUTFLOW        830.    817.    940.    718.   1141.   1324.   1116.    646.   2006.   2164.   2430.   1401.   15533.
  WETLAND ADDITION TO GW         595.    595.    595.    595.    595.    595.    595.    595.    595.    595.    595.    595.    7140.
  INTERFLOW TO GW                487.    487.    487.    487.    487.    487.    487.    487.    487.    487.    487.    487.    5850.
  TOTAL GW ADDED                1082.   1082.   1082.   1082.   1082.   1082.   1082.   1082.   1082.   1082.   1082.   1082.   12990.
OUTFLOW + CHANGE IN GW  R       3981.   4039.   4287.   4021.   4520.   6483.   8916.  21299.  13734.   4308.   4668.   4190.   83745.
  GW OUTFLOW                    1000.   1000.   1000.   1000.   1000.   1000.   1000.   1000.   1000.   1000.   1000.   1000.   12000.
  CHANGE IN GW STORAGE            82.     82.     82.     82.     82.     82.     82.     82.     82.     82.     82.     82.     990.
  SURFACE OUTFLOW               2898.   2957.   3204.   2939.   3437.   5400.   7833.  20217.  11951.   3226.   3585.   3108.   70755.
  GAGED SURFACE OUTFLOW         2890.   2990.   3235.   3025.   3390.   5415.   7925.  20065.  12410.   3300.   3770.   3280.   71695.
  DIFFERENCE (COMP-GAGED)          8.    -33.    -31.    -86.     47.    -15.    -92.    152.   -459.    -74.   -185.   -172.    -940.
SUM OF ABSOLUTE DIFFERENCES =          3305.

                                                  CONSUMPTIVE USE CALCULATIONS
      YEAR MEAN                   OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP   ANNUAL
INPUT PRECIPITATION              1.16     .96    2.03    1.48    1.70    3.03    3.23    1.66    3.39     .24    1.77     .22    20.90
AVERAGE TEMPERATURE             49.10   40.15   22.15   24.15   30.65   39.40   41.95   56.30   61.70   73.00   70.00   61.45    47.31
BLANEY-CRIDDLE "F"               3.80    2.67    1.42    1.59    2.05    3.26    3.76    5.44    6.28    7.57    6.73    5.17    49.75
AGRICULTURAL CROPS
 1 ALFALF UNIT USE (IN.)         1.81     .91     .28     .31     .45    1.04    1.53    3.88    5.63    7.83    6.31    3.81    33.69
 1 ALFALF USE (ACRE-FT)          165.     74.     25.     28.     41.     95.    140.    354.    514.    714.    575.    347.    3071.
 2 PASTRE UNIT USE (IN.)         1.63     .75     .25     .26     .41     .97    1.33    3.44    4.69    6.68    5.52    3.38    29.31
 2 PASTRE USE (ACRE-FT)           94.     43.     14.     15.     23.     56.     77.    198.    270.    385.    318.    195.    1691.
 3 HAY    UNIT USE (IN.)         1.73     .78     .26     .29     .43    1.00    1.45    3.68    5.16    7.26    5.94    3.57    31.56
 3 HAY    USE (ACRE-FT)           24.     11.      4.      4.      6.     14.     21.     52.     73.    102.     84.     50.     446.
 4 GRAIN  UNIT USE (IN.)          .45     .29     .12     .14     .18     .34    1.15    3.98    6.01    5.24    2.43     .74    21.06
 4 GRAIN  USE (ACRE-FT)           35.     23.     10.     11.     14.     26.     89.    309.    467.    407.    188.     57.    1636.
 5 CORN   UNIT USE (IN.)         2.02     .29     .12     .14     .18     .34     .34    2.02    3.46    6.68    6.43    4.23    26.25
 5 CORN   USE (ACRE-FT)           20.      3.      1.      1.      2.      3.      3.     20.     35.     68.     65.     43.     266.
 6 BEETS  UNIT USE (IN.)         2.08     .29     .12     .14     .18     .34     .34    1.96    3.55    6.90    6.55    4.31    26.75
 6 BEETS  USE (ACRE-FT)            9.      1.      0.      0.      0.      1.      1.      8.     15.     30.     28.     19.     115.
 7 TRUCK  UNIT USE (IN.)          .45     .29     .12     .14     .18     .34     .34    1.89    3.41    5.96    4.61     .74    18.47
 7 TRUCK  USE (ACRE-FT)            3.      2.      0.      0.      1.      2.      2.     13.     24.     42.     33.      5.     130.
 8 UR-IDL UNIT USE (IN.)          .71     .30     .11     .12     .15     .36     .51    1.28    1.85    2.80    2.37    1.51    12.08
 8 UR-IDL USE (ACRE-FT)           32.     14.      5.      5.      7.     16.     23.     57.     83.    126.    106.     68.     541.
  CROPLAND P.C.U.                383.    171.     60.     66.     95.    215.    356.   1013.   1481.   1874.   1398.    784.    7896.
ACTUAL CROPLAND C.U.    O        383.    171.     60.     66.     95.    215.    356.   1013.   1481.   1874.   1398.    784.    7896.
WET LAND PHREATOPHYTES
 1 VRONPH UNIT USE (IN.)         3.13    1.49     .56     .59     .92    2.00    2.65    5.70    7.76   11.35    9.40    5.98    51.55
 1 VRONPH USE (ACRE-FT)           40.     19.      7.      8.     12.     26.     34.     73.    100.    146.    121.     77.     665.
 2 DNSPHY UNIT USE (IN.)         2.79    1.30     .48     .48     .80    1.79    2.41    5.23    7.15   10.34    8.55    5.36    46.69
 2 DNSPHY USE (ACRE-FT)          190.     89.     33.     33.     54.    122.    165.    356.    487.    705.    583.    365.    3181.
 3 MEDPHY UNIT USE (IN.)         2.42    1.12     .40     .38     .68    1.58    2.14    4.76    6.53    9.14    7.64    4.74    41.77
 3 MEDPHY USE (ACRE-FT)          101.     46.     16.     16.     28.     66.     91.    197.    271.    388.    317.    197.    1734.
 4 LTPHRY UNIT USE (IN.)         1.89     .93     .33     .32     .64    1.44    1.86    3.71    4.88    7.04    5.88    3.69    32.61
 4 LTPHRY USE (ACRE-FT)           36.     18.      6.      6.     12.     28.     36.     71.     93.    135.    113.     71.     624.
  POTENTIAL WETLAND CU           367.    172.     63.     62.    107.    241.    325.    698.    952.   1373.   1134.    710.    6203.
ACTUAL WETLAND C.U.     O        367.    172.     63.     62.    107.    241.    325.    698.    952.   1373.   1134.    710.    6203.
RESERVOIR EVAPORATION   O        2.79    1.30     .48     .48     .80    1.79    2.41    5.23    7.15   10.34    8.55    5.36    46.69
RESERVOIR EVAPORATION   O         45.     21.      8.      8.     13.     29.     39.     84.    115.    166.    138.     86.     751.

                    MEAN  FLOW VALUES IN CFS FOR WATER QUALITY MODEL
QI     MEAN            33.40   32.40   32.43   31.92   39.88   75.06  158.64  346.66  207.55   72.62   48.07   39.06    93.40
QS     MEAN             3.70    5.47    6.17    5.47    7.01   12.20   19.43   24.95   56.76   16.23   14.69   26.08    16.48
QGI    MEAN            13.50   13.73   15.29   11.67   20.55   21.53   18.75   10.51   33.77   35.13   39.52   23.54    21.45
QD     MEAN            27.44   25.01   25.00   25.00   24.99   25.00   30.00   48.01  143.95  168.04  135.15  107.86    65.66
QIR    MEAN              .00     .03     .00     .00     .03     .00     .00     .37    6.34    9.46    4.46    4.42     2.10
QEF    MEAN            29.99   30.01   29.99   29.99   30.00   29.99   35.01   35.00   35.01   35.00   35.00   35.01    32.51
QO     MEAN            47.14   49.69   52.11   47.79   61.89   87.91  131.64  328.79  200.84   52.46   58.31   52.23    97.73
QGFLO  MEAN            47.00   50.25   52.61   49.20   61.04   88.07  133.18  326.33  208.56   53.67   61.31   55.12    99.03
QDIFF  MEAN              .14    -.56    -.50   -1.40     .85    -.24   -1.55    2.47   -7.71   -1.21   -3.01   -2.90    -1.30
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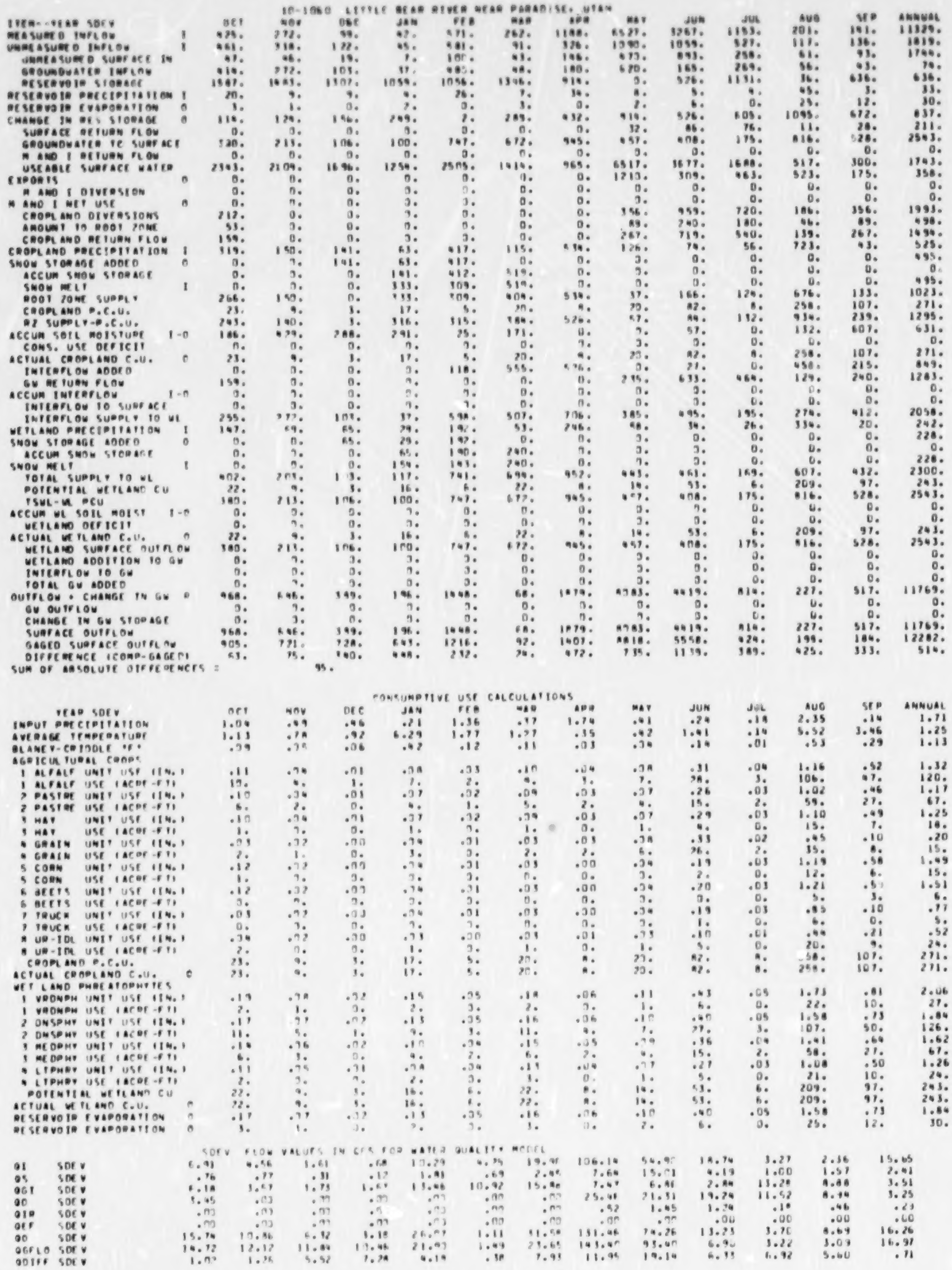
Figure G-6. Continued.



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                                        10-1060  LITTLE BEAR RIVER NEAR PARADISE, UTAH
ITEM--YEAR SDEV                 OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP  ANNUAL
MEASURED INFLOW          I     425.    272.     99.     42.    571.    262.   1188.   6527.   3267.   1153.    201.    141.  11329.
UNMEASURED INFLOW        I     461.    318.    122.     45.    581.     91.    326.   1090.   1059.    527.    117.    136.   1819.
  UNMEASURED SURFACE IN         47.     46.     19.      7.    100.     43.    146.    473.    893.    258.     61.     93.   1744.
  GROUNDWATER INFLOW           414.    272.    103.     37.    485.     48.    180.    620.    165.    269.     56.     43.     74.
  RESERVOIR STORAGE           1547.   1443.   1307.   1059.   1056.   1346.    914.      0.    526.   1131.     36.    636.    636.
RESERVOIR PRECIPITATION I       20.      9.      9.      4.     26.      7.     34.      8.      5.      4.     45.      3.     33.
RESERVOIR EVAPORATION   O        3.      1.      0.      2.      0.      3.      0.      2.      6.      0.     25.     12.     30.
CHANGE IN RES STORAGE   O      114.    124.    156.    249.      2.    285.    432.    914.    526.    605.   1095.    672.    837.
  SURFACE RETURN FLOW            0.      0.      0.      0.      0.      0.      0.     32.     86.     76.     11.     28.    211.
  GROUNDWATER TO SURFACE       380.    213.    106.    100.    747.    672.    945.    457.    408.    175.    816.    528.   2543.
  M AND I RETURN FLOW            0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  USEABLE SURFACE WATER       2343.   2109.   1696.   1254.   2505.   1414.    965.   6517.   3677.   1688.    517.    300.   1743.
EXPORTS                 O        0.      0.      0.      0.      0.      0.      0.   1213.    309.    463.    523.    175.    358.
  M AND I DIVERSION              0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
M AND I NET USE         O        0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  CROPLAND DIVERSIONS          212.      0.      0.      0.      0.      0.      0.    356.    959.    720.    186.    356.   1993.
  AMOUNT TO ROOT ZONE           53.      0.      0.      0.      0.      0.      0.     89.    240.    180.     46.     89.    498.
  CROPLAND RETURN FLOW         159.      0.      0.      0.      0.      0.      0.    267.    719.    540.    139.    267.   1494.
CROPLAND PRECIPITATION  I      319.    150.    141.     63.    417.    115.    534.    126.     74.     56.    723.     43.    525.
SNOW STORAGE ADDED      O        0.      0.    141.     63.    417.      0.      0.      0.      0.      0.      0.      0.    495.
  ACCUM SNOW STORAGE             0.      0.      0.    141.    412.    519.      0.      0.      0.      0.      0.      0.      0.
  SNOW MELT             I        0.      0.      0.    333.    309.    519.      0.      0.      0.      0.      0.      0.    495.
  ROOT ZONE SUPPLY             266.    150.      0.    333.    309.    404.    534.     37.    166.    124.    676.    133.   1023.
  CROPLAND P.C.U.               23.      9.      3.     17.      5.     20.      8.     20.     82.      8.    258.    107.    271.
  RZ SUPPLY-P.C.U.             243.    140.      3.    316.    315.    384.    526.     57.     84.    132.    934.    239.   1295.
ACCUM SOIL MOISTURE   I-O      186.    429.    288.    291.     25.    171.      0.      0.     57.      0.    132.    607.    631.
  CONS. USE DEFICIT              0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
ACTUAL CROPLAND C.U.    O       23.      9.      3.     17.      5.     20.      8.     20.     82.      8.    258.    107.    271.
  INTERFLOW ADDED                0.      0.      0.      0.    118.    555.    576.      0.     21.      0.    458.    215.    849.
  GW RETURN FLOW               159.      0.      0.      0.      0.      0.      0.    235.    633.    464.    129.    240.   1283.
ACCUM INTERFLOW       I-O        0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  INTERFLOW TO SURFACE           0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  INTERFLOW SUPPLY TO WL       255.    272.    103.     37.    598.    507.    706.    385.    495.    195.    274.    412.   2058.
WETLAND PRECIPITATION   I      147.     69.     65.     29.    192.     53.    246.     98.     34.     26.    334.     20.    242.
SNOW STORAGE ADDED      O        0.      0.     65.     29.    192.      0.      0.      0.      0.      0.      0.      0.    228.
  ACCUM SNOW STORAGE             0.      0.      0.     65.    190.    240.      0.      0.      0.      0.      0.      0.      0.
SNOW MELT               I        0.      0.      0.    154.    143.    240.      0.      0.      0.      0.      0.      0.    228.
  TOTAL SUPPLY TO WL           402.    203.    103.    117.    741.    699.    952.    443.    461.    169.    607.    432.   2300.
  POTENTIAL WETLAND CU          22.      9.      3.     16.      6.     22.      8.     14.     53.      6.    209.     97.    243.
  TSWL-WL PCU                  380.    213.    106.    100.    747.    672.    945.    457.    408.    175.    816.    528.   2543.
ACCUM WL SOIL MOIST   I-O        0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  WETLAND DEFICIT                0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
ACTUAL WETLAND C.U.     O       22.      9.      3.     16.      6.     22.      8.     14.     53.      6.    209.     97.    243.
  WETLAND SURFACE OUTFLOW      380.    213.    106.    100.    747.    672.    945.    457.    408.    175.    816.    528.   2543.
  WETLAND ADDITION TO GW         0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  INTERFLOW TO GW                0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  TOTAL GW ADDED                 0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
OUTFLOW + CHANGE IN GW  O      968.    646.    349.    196.   1448.     68.   1879.   8783.   4419.    814.    227.    517.  11769.
  GW OUTFLOW                     0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  CHANGE IN GW STORAGE           0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  SURFACE OUTFLOW              968.    646.    399.    196.   1448.     68.   1879.   8783.   4419.    814.    227.    517.  11769.
  GAGED SURFACE OUTFLOW        905.    721.    728.    643.   1216.     92.   1407.   8818.   5558.    424.    199.    184.  12282.
  DIFFERENCE (COMP-GAGED)       63.     75.    380.    448.    232.     24.    472.    735.   1139.    389.    425.    333.    514.
SUM OF ABSOLUTE DIFFERENCES =                95.

                                                 CONSUMPTIVE USE CALCULATIONS
        YEAR SDEV               OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP  ANNUAL
INPUT PRECIPITATION            1.04     .49     .46     .21    1.36     .17    1.74     .41     .24     .18    2.35     .14    1.71
AVERAGE TEMPERATURE            1.13     .78     .92    6.29    1.77    1.27     .35     .42    1.41     .14    5.52    3.46    1.25
BLANEY-CRIDDLE "F"              .29     .25     .06     .42     .12     .11     .03     .34     .14     .01     .53     .29    1.13
AGRICULTURAL CROPS
 1 ALFALF UNIT USE (IN.)        .11     .24     .01     .08     .03     .10     .04     .08     .31     .04    1.16     .52    1.32
 1 ALFALF USE (ACRE-FT)         19.      4.      1.      7.      2.      4.      3.      7.     28.      3.    106.     47.    120.
 2 PASTRE UNIT USE (IN.)        .10     .34     .01     .07     .02     .09     .03     .07     .26     .03    1.02     .46    1.17
 2 PASTRE USE (ACRE-FT)          6.      2.      0.      4.      1.      5.      2.      4.     15.      2.     59.     27.     67.
 3 HAY    UNIT USE (IN.)        .10     .04     .01     .07     .02     .09     .03     .07     .29     .03    1.10     .49    1.25
 3 HAY    USE (ACRE-FT)          1.      0.      0.      1.      0.      1.      0.      1.      4.      0.     15.      7.     18.
 4 GRAIN  UNIT USE (IN.)        .03     .02     .00     .04     .01     .03     .03     .08     .33     .02     .45     .10     .20
 4 GRAIN  USE (ACRE-FT)          2.      1.      0.      3.      0.      2.      2.      6.     26.      2.     35.      8.     15.
 5 CORN   UNIT USE (IN.)        .12     .02     .00     .04     .01     .03     .00     .04     .19     .03    1.19     .58    1.49
 5 CORN   USE (ACRE-FT)          1.      0.      0.      0.      0.      0.      0.      0.      2.      0.     12.      6.     15.
 6 BEETS  UNIT USE (IN.)        .12     .02     .00     .04     .01     .03     .00     .04     .20     .03    1.21     .59    1.51
 6 BEETS  USE (ACRE-FT)          0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      5.      3.      6.
 7 TRUCK  UNIT USE (IN.)        .03     .02     .03     .04     .01     .03     .00     .04     .19     .03     .85     .10     .77
 7 TRUCK  USE (ACRE-FT)          0.      0.      0.      0.      0.      0.      0.      0.      1.      0.      6.      0.      5.
 8 UR-IDL UNIT USE (IN.)        .34     .02     .00     .03     .00     .03     .01     .03     .10     .01     .44     .21     .52
 8 UR-IDL USE (ACRE-FT)          2.      0.      0.      1.      0.      1.      0.      1.      5.      0.     20.      9.     24.
  CROPLAND P.C.U.               23.      9.      3.     17.      5.     20.      8.     20.     82.      8.    258.    107.    271.
ACTUAL CROPLAND C.U.    O       23.      9.      3.     17.      5.     20.      8.     20.     82.      8.    258.    107.    271.
WET LAND PHREATOPHYTES
 1 VRDNPH UNIT USE (IN.)        .19     .28     .32     .15     .05     .18     .06     .11     .43     .05    1.73     .81    2.06
 1 VRDNPH USE (ACRE-FT)          2.      1.      0.      2.      0.      2.      0.      1.      6.      0.     22.     10.     27.
 2 DNSPHY UNIT USE (IN.)        .17     .27     .02     .13     .05     .16     .06     .10     .40     .05    1.58     .73    1.84
 2 DNSPHY USE (ACRE-FT)         11.      5.      1.      9.      3.     11.      4.      7.     27.      3.    107.     50.    126.
 3 MEDPHY UNIT USE (IN.)        .14     .16     .02     .10     .04     .15     .05     .09     .36     .04    1.41     .64    1.62
 3 MEDPHY USE (ACRE-FT)          6.      3.      0.      4.      2.      6.      2.      4.     15.      2.     58.     27.     67.
 4 LTPHRY UNIT USE (IN.)        .11     .25     .01     .08     .04     .13     .04     .07     .27     .03    1.08     .50    1.26
 4 LTPHRY USE (ACRE-FT)          2.      0.      0.      2.      0.      3.      0.      1.      5.      0.     21.     10.     24.
  POTENTIAL WETLAND CU          22.      9.      3.     16.      6.     22.      8.     14.     53.      6.    209.     97.    243.
ACTUAL WETLAND C.U.     O       22.      9.      3.     16.      6.     22.      8.     14.     53.      6.    209.     97.    243.
RESERVOIR EVAPORATION   O       .17     .27     .32     .13     .05     .16     .06     .10     .40     .05    1.58     .73    1.84
RESERVOIR EVAPORATION   O        3.      1.      0.      2.      0.      3.      0.      2.      6.      0.     25.     12.     30.

                           SDEV  FLOW VALUES IN CFS FOR WATER QUALITY MODEL
QI     SDEV               6.93    4.56    1.61     .68   10.29    4.75   19.90  106.14   54.90   18.74    3.27    2.36   15.65
QS     SDEV                .76     .77     .31     .12    1.81     .69    2.46    7.64   15.01    4.19    1.00    1.57    2.41
QGI    SDEV               6.18    3.67    1.73    1.67   13.46   10.92   15.86    7.47    6.86    2.84   13.28    8.88    3.51
QD     SDEV               3.45     .03     .00     .00     .00     .00     .00   25.40   21.31   19.24   11.52    8.44    3.25
QIR    SDEV                .00     .00     .00     .50     .00     .00     .00     .52    1.45    1.24     .18     .46     .23
QEF    SDEV                .00     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00     .60
QO     SDEV              15.74   10.86    6.32    3.18   26.07    1.11   31.58  131.46   74.26   13.23    3.70    8.69   16.26
QGFLO  SDEV              14.72   12.12   11.84   10.46   21.93    1.49   23.65  143.40   93.40    6.90    3.22    3.09   16.97
QDIFF  SDEV               1.02    1.26    5.52    7.28    4.19     .38    7.93   11.95   19.14    6.33    6.92    5.60     .71
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Figure G-6. Continued.

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INPUT DATA FOR              10-1076  LITTLE BEAR RIVER BELOW PARADISE AT WELLSVILLE, UTAH
LBR-1   2 12  8  5  1  1  1  1  0  1  1  1  1  1  1  1  1  0  1  .30 1.00 1.000 1.000 1.000  .350  .100  35.0  24.0
LBR-1       9355.      1600.      3950.    4370.   5.00   3.00    .00       3500.        500.     .100      3500.     11694.          0.          0.
LBR-1    2      1.000      1.000        372.      1600.       1600.
ITEM--YEAR 1967                    OCT      NOV      DEC      JAN      FEB      MAR      APR      MAY      JUN      JUL      AUG      SEP   ANNUAL
CROP GW-RETURN FLO COEF          1.000    1.000    1.000    1.000    1.000    1.000    1.000    1.000     .951     .936     .940     .913
SURFACE TIF COEFFICIENTS          .022     .012     .040     .074     .010     .009     .182     .255     .939    1.000     .103     .400
INTERFLOW SWL COEF                .134     .081     .000     .012     .369     .213     .000     .376     .647     .708     .394     .267
PROPORTION DAYLIGHT HOURS        .0774    .0665    .0642    .0660    .0668    .0828    .0896    .1007    .1018    .1037    .0962    .0842
PROP CROP AREAS     .284     .195     .023     .247     .027     .010     .016     .198
    CROP AREAS     2657.    1824.     215.    2311.     253.      94.     150.    1852.    9355.
  1 ALFALF K COEF                  .83      .90      .65      .64      .73      .87      .99     1.15     1.19     1.09     1.04      .98
  2 PASTRE K COEF                  .80      .74      .58      .55      .66      .81      .86     1.02      .99      .93      .91      .87
  3 HAY    K COEF                  .85      .77      .62      .60      .70      .81      .94     1.09     1.09     1.01      .98      .92
  4 GRAIN  K COEF                  .22      .29      .29      .29      .29      .28      .74     1.18     1.27      .73      .40      .19
  5 CORN   K COEF                  .99      .29      .29      .29      .29      .28      .22      .60      .73      .93     1.06     1.09
  6 BEETS  K COEF                 1.02      .29      .29      .29      .29      .28      .22      .58      .75      .96     1.08     1.11
  7 TRUCK  K COEF                  .22      .29      .29      .29      .29      .28      .22      .56      .72      .83      .76      .19
  8 UR-IDL K COEF                  .35      .30      .25      .25      .25      .30      .33      .38      .39      .39      .39      .39
PROP WLPH AREAS     .135     .221     .219     .234     .191
    WLPH AREAS     216.     354.     350.     374.     306.    1600.
  1 VPDNPH K COEF                 1.54     1.47     1.31     1.23     1.50     1.67     1.71     1.69     1.64     1.58     1.55     1.54
  2 DNSPHY K COEF                 1.37     1.29     1.12     1.01     1.30     1.49     1.56     1.55     1.51     1.44     1.41     1.38
  3 MEDPHY K COEF                 1.19     1.10      .93      .80     1.10     1.32     1.41     1.41     1.38     1.30     1.26     1.22
  4 LTPHRY K COEF                  .93      .91      .77      .67     1.05     1.20     1.20     1.10     1.03      .98      .97      .95
  5 VLTPHY K COEF                  .35      .30      .25      .25      .25      .30      .33      .38      .39      .39      .39      .39

WATER  K COEF                     1.37     1.28     1.12     1.01     1.30     1.49     1.56     1.55     1.51     1.44     1.41     1.38
                          MEASURED INFLOW          1
  1 101060  1967                 2250.    2480.    2720.    2570.    2530.    5350.    8920.   26300.   16340.    3600.    3910.    3410.   80380.
  1 101060  1968                 3530.    3500.    3750.    3480.    4250.    5480.    6930.   13830.    8480.    3000.    3630.    3150.   63010.
                          MEASURED IMPORTS         1
  1 HYRM C  1967                    0.       0.       0.       0.       0.       0.       0.       0.    2368.    3316.    2143.    1349.    9176.
  1 HYRM C  1968                    0.       0.       0.       0.       0.       0.       0.    1711.    2805.    2661.    1404.    1101.    9682.
                            CROPLAND DIVERSIONS
  1  CD     1967                    0.       0.       0.       0.       0.       0.       0.     184.    5760.    6762.    5138.    3218.   21062.
  1  CD     1968                  300.       0.       0.       0.       0.       0.       0.    2301.    6078.    5822.    3221.    2398.   20120.
                          INPUT PRECIPITATION
  1 LOGUSU  1967                    0.       1.       2.       2.       0.       3.       4.       3.       4.       0.       0.       0.      19.
  1 LOGUSU  1968                    2.       0.       2.       1.       3.       3.       2.       1.       3.       0.       3.       0.      22.
                          AVERAGE TEMPERATURE
  1 LOGUSU  1967                   48.      41.      23.      29.      32.      38.      42.      54.      61.      73.      74.      64.     578.
  1 LOGUSU  1968                   53.      40.      21.      20.      29.      40.      42.      54.      63.      73.      66.      59.     557.
                            M AND I DIVERSION
  1 MIDV    1967                    0.       0.       0.       0.       0.       0.       0.       0.       0.     542.       0.       0.     542.
  1 MIDV    1968                  300.     300.     300.     300.     300.     300.     300.     300.     300.     300.     300.     300.    3600.
                          M AND I NET USE          0
  1 MIUS    1967                 -615.    -595.    -676.    -676.    -611.    -676.    -952.    -738.    -833.    -196.    -738.    -714.   -8020.
  1 MIUS    1968                 -315.    -295.    -315.    -376.    -311.    -561.    -295.    -315.    -295.    -315.    -315.    -295.   -4003.
                          UNMEASURED INFLOW        1
  1 TIF     1967                 2175.    1893.    1934.    2103.    1932.    2410.    1820.    1815.    1920.     338.    1310.    2327.   21977.
  1 TIF     1968                 2853.    2072.    2374.    2167.    2794.    2224.    1522.    1169.    1315.     234.    1190.    2136.   22050.
                            RESERVOIR STORAGE
  1 HYRES   1967                 5680.    8260.   10090.   10310.   10310.   14390.   15570.   15570.   15420.   11580.   10140.   10610.  137930.
  1 HYRES   1968                10520.   10520.   10480.   10480.   10480.   13590.   13500.   15760.   14670.   10790.    9840.   10180.  140810.
                          EXPORTS                  0
  1  EXPO   1967                  646.       0.       0.       0.       0.       0.       0.     400.     922.    3590.    2790.    1863.   10211.
  1  EXPO   1968                    0.       0.       0.       0.       0.       0.       0.    2032.    1032.    3158.    1458.     991.    8671.

                            GAGED SURFACE OUTFLOW
  1 101076  1967                 1590.    1210.    2370.    3900.    3700.    2610.    9980.   26910.   16460.    1640.    2020.    2190.   74580.
  1 101076  1968                 4530.    4580.    4730.    4780.    5120.    4580.    7920.    9720.    7380.    1800.    3390.    3650.   62180.
                            GW OUTFLOW
  1 GWOF    1967                 1200.    1200.    1200.    1200.    1500.    1500.    1500.    1500.    2000.    1800.    1500.    1500.   17600.
  1 GWOF    1968                 1500.    1400.    1300.    1250.    1500.    1500.    1500.    1500.    2000.    1800.    1500.    1500.   18250.
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Figure G-6. Continued.

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                                           10-1076  LITTLE BEAR RIVER BELOW PARADISE AT WELLSVILLE, UTAH
ITEM--YEAR 1967                   OCT      NOV      DEC      JAN      FEB      MAR      APR      MAY      JUN      JUL      AUG      SEP    ANNUAL
MEASURED INFLOW          I      2250.    2480.    2720.    2570.    2530.    5350.    4920.   26300.   16340.    3600.    3910.    3410.    80380.
MEASURED IMPORTS         I         0.       0.       0.       0.       0.       0.       0.       0.    2368.    3316.    2143.    1349.     9176.
UNMEASURED INFLOW        I      2125.    1943.    1934.    2103.    1932.    2410.    1870.    1815.    1920.     338.    1310.    2327.    21977.
  UNMEASURED SURFACE IN           47.      21.      77.     156.      19.      22.     331.     463.    1803.     338.     135.     931.     4345.
  GROUNDWATER INFLOW            2078.    1923.    1857.    1947.    1913.    2388.    1489.    1352.     117.       0.    1175.    1396.    17632.
  RESERVOIR STORAGE             5680.    8267.   10090.   10310.   10310.   14390.   15570.   15570.   15420.   11580.   10140.   10610.    10610.
RESERVOIR PRECIPITATION I         11.      41.      53.      51.      23.     102.     138.      29.     110.      11.       0.       4.      576.
RESERVOIR EVAPORATION    O        83.      42.      15.      18.      26.      52.      76.     160.     213.     322.     300.     182.     1488.
CHANGE IN RES STORAGE    O      1730.    2587.    1830.     220.       0.    4080.    1180.       0.    -150.   -3840.   -1440.     470.     6660.
  SURFACE RETURN FLOW              0.       0.       0.       0.       0.       0.       0.       0.     198.     303.     216.     196.      912.
  GROUNDWATER TO SURFACE         739.     639.     632.     714.     834.     916.     264.     160.     962.     936.    2019.    1633.    10046.
  M AND I RETURN FLOW            615.     595.     676.     676.     611.     676.     952.     738.     833.     738.     738.     714.     8562.
  USEABLE SURFACE WATER         7531.    9415.   17403.   14238.   13901.   17324.   24914.   43100.   37971.   24341.   20441.   18194.   243779.
EXPORTS                  O       646.       0.       0.       0.       0.       0.       0.     400.     922.    3590.    2790.    1863.    10211.
  M AND I DIVERSION                0.       0.       0.       0.       0.       0.       0.       0.       0.     542.       0.       0.      542.
M AND I NET USE          O      -615.    -595.    -676.    -676.    -611.    -676.    -952.    -738.    -833.    -196.    -738.    -714.    -8020.
  CROPLAND DIVERSIONS              0.       0.       0.       0.       0.       0.       0.     144.    5760.    6762.    5138.    3218.    21062.
  AMOUNT TO ROOT ZONE              0.       0.       0.       0.       0.       0.       0.      55.    1728.    2029.    1541.     965.     6319.
  CROPLAND RETURN FLOW             0.       0.       0.       0.       0.       0.       0.     129.    4032.    4733.    3597.    2253.    14743.
CROPLAND PRECIPITATION   I       335.    1321.    1333.    1271.     577.    2573.    3477.     741.    2775.     288.       8.      94.    14492.
SNOW STORAGE ADDED       O         0.       0.    1333.    1271.     577.       0.       0.       0.       0.       0.       0.       0.     3181.
  ACCUM SNOW STORAGE               0.       0.       0.    1333.    1406.     416.       0.       0.       0.       0.       0.       0.        0.
  SNOW MELT              I         0.       0.       0.    1198.    1567.     416.       0.       0.       0.       0.       0.       0.     3181.
  ROOT ZONE SUPPLY               335.    1321.       0.    1198.    1567.    2989.    3477.     796.    4503.    2317.    1549.    1059.    20811.
  CROPLAND P.C.U.                901.     441.     154.     194.     244.     497.     896.    2458.    3495.    4605.    3864.    2114.    19862.
  RZ SUPPLY-P.C.U.              -565.     593.    -154.    1004.    1323.    2493.    2581.   -1663.    1008.   -2288.   -2315.   -1055.      949.
ACCUM SOIL MOISTURE    I-O      4300.    3735.    4715.    4162.    5165.    6488.    8981.   11562.    9900.   10908.    8620.    6305.     5249.
  CONS. USE DEFICIT                0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.        0.
ACTUAL CROPLAND C.U.     O       901.     441.     154.     194.     244.     497.     896.    2458.    3495.    4605.    3864.    2114.    19862.
  INTERFLOW ADDED                  0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.        0.
  GW RETURN FLOW                   0.       0.       0.       0.       0.       0.       0.     129.    3834.    4430.    3381.    2057.    13831.
ACCUM INTERFLOW        I-O      3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.     3500.
  INTERFLOW TO SURFACE           739.     638.     632.     714.     834.     916.     264.     160.     962.     936.    2019.    1633.    10046.
  INTERFLOW SUPPLY TO WL         114.      56.       0.       9.     254.     248.       0.      96.    1764.    2269.    1312.     595.     6718.
WETLAND PRECIPITATION    I        57.     175.     228.     217.      99.     440.     595.     127.     475.      49.       1.      16.     2479.
SNOW STORAGE ADDED       O         0.       0.     228.     217.      99.       0.       0.       0.       0.       0.       0.       0.      544.
  ACCUM SNOW STORAGE               0.       0.       0.     228.     243.      71.       0.       0.       0.       0.       0.       0.        0.
SNOW MELT                I         0.       0.       0.     205.     268.      71.       0.       0.       0.       0.       0.       0.      544.
  TOTAL SUPPLY TO WL             172.     231.       0.     214.     522.     759.     595.     223.    2239.    2319.    1314.     611.    16446.
  POTENTIAL WETLAND CU           274.     140.      50.      58.      87.     177.     258.     536.     711.    1076.    1004.     611.     4983.
  TSWL-WL PCU                   -103.      91.     -50.     155.     434.     582.     337.    -313.    1527.    1243.     310.      -0.     4213.
ACCUM WL SOIL MOIST    I-O      1600.    1497.    1588.    1534.    1600.    1600.    1600.    1600.    1787.    1600.    1600.    1600.     1599.
  WETLAND DEFICIT                  0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.        0.
ACTUAL WETLAND C.U.      O       274.     140.      50.      58.      87.     177.     258.     536.     711.    1076.    1004.     611.     4983.
  WETLAND SURFACE OUTFLOW          0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.        0.
  WETLAND ADDITION TO GW           0.       0.       0.      99.     434.     582.     337.       0.    1214.    1243.     310.       0.     4214.
  INTERFLOW TO GW               1225.    1225.    1225.    1225.    1225.    1225.    1225.    1225.    1225.    1225.    1225.    1225.    14700.
  TOTAL GW ADDED                1225.    1225.    1225.    1319.    1659.    1807.    1562.    1225.    2439.    2468.    1535.    1225.    18914.
OUTFLOW + CHANGE IN GW   O      2430.    2380.    3538.    5247.    5251.    4741.   10911.   28171.   18308.    4334.    3907.    3728.    92948.
  GW OUTFLOW                    1200.    1200.    1200.    1200.    1500.    1500.    1500.    1500.    2000.    1800.    1500.    1500.    17600.
  CHANGE IN GW STORAGE            25.      25.      25.     119.     159.     307.      62.    -275.     439.     668.      35.    -275.     1314.
  SURFACE OUTFLOW               1205.    1155.    2313.    3928.    3591.    2934.    9349.   26946.   15869.    1867.    2373.    2503.    74034.
  GAGED SURFACE OUTFLOW         1590.    1210.    2370.    3900.    3700.    2610.    9980.   26910.   16460.    1640.    2020.    2190.    74580.
  DIFFERENCE (COMP-GAGED)       -385.     -55.     -57.      28.    -109.     324.    -631.      36.    -591.     227.     353.     313.     -546.
SUM OF ABSOLUTE DIFFERENCES =             3108.

                                                         CONSUMPTIVE USE CALCULATIONS
      YEAR 1967                   OCT      NOV      DEC      JAN      FEB      MAR      APR      MAY      JUN      JUL      AUG      SEP    ANNUAL
INPUT PRECIPITATION               .43     1.31     1.71     1.63      .74     3.30     4.46      .95     3.56      .37      .01      .12     18.59
AVERAGE TEMPERATURE             48.30    43.70    22.80    28.60    31.90    38.50    42.20    53.70    60.70    73.10    73.90    63.90     48.19
BLANEY-CRIDDLE 'F'               3.74     2.71     1.46     1.83     2.13     3.19     3.78     5.41     6.18     7.58     7.11     5.38     50.55
AGRICULTURAL CROPS
 1 ALFALF UNIT USE (IN.)         1.74      .84      .29      .36      .47      .98     1.56     3.82     5.41     7.85     7.13     4.17     34.62
 1 ALFALF USE (ACRE-FT)          384.     187.      63.      83.     103.     216.     345.     847.    1198.    1739.    1579.     924.     7666.
 2 PASTRE UNIT USE (IN.)         1.56      .78      .25      .31      .42      .91     1.35     3.39     4.50     6.70     6.24     3.70     30.13
 2 PASTRE USE (ACRE-FT)          237.     119.      39.      47.      64.     138.     206.     516.     685.    1019.     949.     563.     4581.
 3 HAY    UNIT USE (IN.)         1.66      .81      .27      .34      .45      .93     1.48     3.63     4.96     7.28     6.72     3.92     32.44
 3 HAY    USE (ACRE-FT)           30.      15.       5.       6.       8.      17.      27.      65.      89.     131.     120.      70.      582.
 4 GRAIN  UNIT USE (IN.)          .43      .31      .13      .16      .19      .31     1.16     3.92     5.78     5.26     2.74      .81     21.20
 4 GRAIN  USE (ACRE-FT)           83.      59.      25.      32.      36.      61.     224.     756.    1112.    1013.     528.     156.     4083.
 5 CORN   UNIT USE (IN.)         1.93      .31      .13      .16      .19      .31      .35     2.30     3.32     6.70     7.27     4.64     27.30
 5 CORN   USE (ACRE-FT)           41.       6.       3.       3.       4.       7.       7.      42.      70.     141.     153.      98.      575.
 6 BEETS  UNIT USE (IN.)         1.99      .31      .13      .16      .19      .31      .35     1.93     3.41     6.92     7.41     4.73     27.82
 6 BEETS  USE (ACRE-FT)           16.       2.       0.       1.       1.       2.       3.      15.      27.      54.      58.      37.      217.
 7 TRUCK  UNIT USE (IN.)          .43      .31      .13      .16      .19      .31      .35     1.86     3.28     5.98     5.21      .81     19.01
 7 TRUCK  USE (ACRE-FT)            5.       4.       2.       2.       2.       4.       4.      23.      41.      75.      65.      10.      237.
 8 UR-IDL UNIT USE (IN.)          .68      .32      .11      .14      .16      .34      .52     1.26     1.77     2.81     2.67     1.66     12.45
 8 UR-IDL USE (ACRE-FT)          105.      49.      17.      22.      25.      52.      80.     195.     274.     434.     413.     256.     1922.
  CROPLAND P.C.U.                901.     441.     154.     194.     244.     497.     896.    2458.    3495.    4605.    3864.    2114.    19862.
ACTUAL CROPLAND C.U.     O       901.     441.     154.     194.     244.     497.     896.    2458.    3495.    4605.    3864.    2114.    19862.
WET LAND PHREATOPHYTES
 1 VRDNPH UNIT USE (IN.)         3.00     1.55      .58      .70      .96     1.87     2.69     5.62     7.46    11.39    10.63     6.56     53.00
 1 VRDNPH USE (ACRE-FT)           54.      28.      10.      13.      17.      34.      48.     101.     134.     205.     191.     118.      954.
 2 ONSPHY UNIT USE (IN.)         2.67     1.35      .49      .57      .83     1.67     2.45     5.15     6.87    10.38     9.67     5.88     47.99
 2 ONSPHY USE (ACRE-FT)           79.      40.      14.      17.      24.      49.      72.     152.     202.     306.     285.     173.     1414.
 3 MEDPHY UNIT USE (IN.)         2.32     1.16      .41      .45      .70     1.48     2.22     4.69     6.28     9.37     8.64     5.20     42.92
 3 MEDPHY USE (ACRE-FT)           68.      34.      12.      13.      21.      43.      65.     137.     183.     274.     252.     152.     1253.
 4 LTPHRY UNIT USE (IN.)         1.81      .96      .34      .38      .67     1.35     1.89     3.66     4.69     7.06     6.65     4.05     33.50
 4 LTPHRY USE (ACRE-FT)           57.      30.      11.      12.      21.      42.      59.     114.     146.     220.     208.     126.     1045.
 5 VLTPHY UNIT USE (IN.)          .68      .32      .11      .14      .16      .34      .52     1.26     1.77     2.81     2.67     1.66     12.45
 5 VLTPHY USE (ACRE-FT)           17.       8.       3.       4.       4.       9.      13.      32.      45.      72.      68.      42.      317.
  POTENTIAL WETLAND CU           274.     140.      50.      58.      87.     177.     258.     536.     711.    1076.    1004.     611.     4983.
ACTUAL WETLAND C.U.      O       274.     140.      50.      58.      87.     177.     258.     536.     711.    1076.    1004.     611.     4983.
RESERVOIR EVAPORATION    O       2.67     1.35      .49      .57      .83     1.67     2.45     5.15     6.87    10.38     9.67     5.88     47.99
RESERVOIR EVAPORATION    O        83.      42.      15.      18.      26.      52.      76.     160.     213.     322.     300.     182.     1488.

                             1967  FLOW VALUES IN CFS FOR WATER QUALITY MODEL
QI     1967             36.59    41.68    44.24    41.80    45.56    87.01   149.91   427.73   274.60    58.55    63.59    57.31   111.03
QS     1967               .76      .39     1.26     2.57      .35      .35     5.57     7.53    30.30     5.50     2.19    15.64     6.00
QGI    1967             12.02    10.73    10.27    11.61     7.81    14.99     4.43     2.60    16.17    15.72    32.83    27.44    13.88
QD     1967             10.51      .00      .00      .00      .00      .00      .00     9.50   112.29   177.17   128.94    85.39    43.95
QIR    1967               .00      .00      .00      .00      .00      .00      .00      .00     3.32     4.93     3.51     3.29     1.26
QEF    1967             10.00    10.00    10.99    10.99    11.00    10.99    16.00    12.00    14.00    12.00    12.00    12.00    11.83
QO     1967             19.60    19.42    37.61    63.88    64.67    47.71   157.12   438.24   266.69    30.36    38.59    42.07   102.26
QGFLO  1967             25.86    20.33    38.54    63.43    66.62    42.45   167.72   437.65   276.62    26.67    32.85    36.80   103.02
QDIFF  1967             -6.26     -.92     -.93      .46    -1.96     5.26   -10.60      .59    -9.93     3.69     5.74     5.27     -.75
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Figure G-6. Continued.

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                       13-1076  LITTLE BEAR RIVER BELOW PARADISE AT WELLSVILLE, UTAH
ITEM--YEAR 1968                     OCT      NOV      DEC      JAN      FEB      MAR      APR      MAY      JUN      JUL      AUG      SEP   ANNUAL
MEASURED INFLOW             I     3530.    3500.    3750.    3480.    4250.    5480.    6930.   13830.    8483.    3000.    3630.    3150.   63010.
MEASURED IMPORTS            I        0.       0.       0.       0.       0.       0.       0.    1711.    2805.    2661.    1404.    1101.    9682.
UNMEASURED INFLOW           I     2853.    2372.    2074.    2167.    2794.    2224.    1572.    1169.    1315.     234.    1190.    2136.   22050.
  UNMEASURED SURFACE IN             63.      28.      83.     160.      28.      20.     277.     298.    1235.     234.     123.     854.    3403.
  GROUNDWATER INFLOW              2790.    2344.    1991.    2007.    2766.    2204.    1245.     871.      80.       0.    1067.    1282.   18647.
  RESERVOIR STORAGE              10520.   10520.   10480.   10480.   10480.   13590.   13500.   15760.   14670.   10790.    9840.   10180.   10180.
RESERVOIR PRECIPITATION I           59.      19.      73.      42.      82.      86.      62.      42.     100.       3.     107.      10.     685.
RESERVOIR EVAPORATION   O           90.      39.      14.      12.      24.      59.      74.     164.     230.     320.     231.     150.    1407.
CHANGE IN RES STORAGE   O          -90.       0.     -40.       0.       0.    3110.     -90.    2260.   -1090.   -3880.    -950.     340.    -430.
  SURFACE RETURN FLOW                0.       0.       0.       0.       0.       0.       0.       0.     208.     261.     135.     146.     751.
  GROUNDWATER TO SURFACE          1537.    1028.     766.     772.     972.     984.     713.     784.    1024.     756.    1189.    1165.   11691.
  M AND I RETURN FLOW              615.     595.     615.     676.     611.     861.     595.     615.     595.     615.     615.     595.    7603.
  USEABLE SURFACE WATER          16324.   15652.   15793.   15598.   16400.   17852.   22093.   30616.   29977.   21881.   17762.   16711.  236658.
EXPORTS                 O            0.       0.       0.       0.       0.       0.       0.    2032.    1032.    3158.    1458.     991.    8671.
  M AND I DIVERSION                300.     300.     300.     300.     300.     300.     300.     300.     300.     300.     300.     300.    3600.
M AND I NET USE         O         -315.    -295.    -315.    -376.    -311.    -561.    -295.    -315.    -295.    -315.    -315.    -295.   -4003.
  CROPLAND DIVERSIONS              300.       0.       0.       0.       0.       0.       0.    2301.    6078.    5822.    3221.    2398.   20120.
  AMOUNT TO ROOT ZONE               90.       0.       0.       0.       0.       0.       0.     690.    1823.    1747.     966.     719.    6036.
  CROPLAND RETURN FLOW             210.       0.       0.       0.       0.       0.       0.    1611.    4255.    4075.    2255.    1679.   14084.
CROPLAND PRECIPITATION  I         1481.     483.    1840.    1045.    2074.    2159.    1559.    1068.    2510.      86.    2682.     249.   17237.
SNOW STORAGE ADDED      O            0.       0.    1840.    1045.    2074.       0.       0.       0.       0.       0.       0.       0.    4958.
  ACCUM SNOW STORAGE                 0.       0.       0.    1840.    2884.    2281.       0.       0.       0.       0.       0.       0.       0.
  SNOW MELT             I            0.       0.       0.       0.    2677.    2281.       0.       0.       0.       0.       0.       0.    4958.
  ROOT ZONE SUPPLY                1571.     483.       0.       0.    2677.    4440.    1559.    1758.    4334.    1832.    3648.     969.   23273.
  CROPLAND P.C.U.                  980.     408.     145.     134.     224.     566.     867.    2528.    3780.    4575.    2973.    1743.   18922.
  RZ SUPPLY-P.C.U.                 591.      75.    -145.    -134.    2453.    3874.     693.    -770.     553.   -2743.     675.    -774.    4350.
ACCUM SOIL MOISTURE   I-O         5249.    5841.    5916.    5771.    5630.    8091.   11694.   11694.   10924.   11478.    8735.    9410.    8636.
  CONS. USE DEFICIT                  0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
ACTUAL CROPLAND C.U.    O          980.     408.     145.     134.     224.     566.     867.    2528.    3780.    4575.    2973.    1743.   18922.
  INTERFLOW ADDED                    0.       0.       0.       0.       0.     272.     693.       0.       0.       0.       0.       0.     964.
  GW RETURN FLOW                   210.       0.       0.       0.       0.       0.       0.    1611.    4046.    3815.    2119.    1533.   13333.
ACCUM INTERFLOW       I-O         3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.
  INTERFLOW TO SURFACE            1537.    1028.     766.     772.     972.     984.     713.     784.    1024.     756.    1189.    1165.   11691.
  INTERFLOW SUPPLY TO WL           238.      91.       0.       9.     569.     266.       0.     472.    1877.    1833.     773.     424.    6553.
WETLAND PRECIPITATION   I          253.      83.     315.     179.     355.     369.     267.     183.     429.      15.     459.      43.    2948.
SNOW STORAGE ADDED      O            0.       0.     315.     179.     355.       0.       0.       0.       0.       0.       0.       0.     848.
  ACCUM SNOW STORAGE                 0.       0.       0.     315.     493.     390.       0.       0.       0.       0.       0.       0.       0.
SNOW MELT               I            0.       0.       0.       0.     458.     390.       0.       0.       0.       0.       0.       0.     848.
  TOTAL SUPPLY TO WL               491.     173.       0.       9.    1027.    1026.     267.     655.    2307.    1848.    1232.     467.   40003.
  POTENTIAL WETLAND CU             299.     129.      47.      43.      80.     202.     249.     551.     769.    1069.     772.     504.    4713.
  TSWL-WL PCU                      193.      44.     -47.     -31.     946.     824.      17.     104.    1537.     779.     459.     -37.    4788.
ACCUM WL SOIL MOIST   I-O         1599.    1600.    1600.    1553.    1522.    1600.    1600.    1600.    1600.    1600.    1600.    1600.    1563.
  WETLAND DEFICIT                    0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
ACTUAL WETLAND C.U.     O          299.     129.      47.      43.      80.     202.     249.     551.     769.    1069.     772.     504.    4713.
  WETLAND SURFACE OUTFLOW            0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
  WETLAND ADDITION TO GW           192.      44.       0.       0.     868.     824.      17.     104.    1537.     779.     459.       0.    4825.
  INTERFLOW TO GW                 1225.    1225.    1225.    1225.    1225.    1225.    1225.    1225.    1225.    1225.    1225.    1225.   14700.
  TOTAL GW ADDED                  1417.    1269.    1225.    1225.    2093.    2049.    1242.    1329.    2762.    2004.    1684.    1225.   19525.
OUTFLOW + CHANGE IN GW  O         6621.    6101.    6238.    6043.    7713.    6011.    9535.   11552.   10659.    3815.    4627.    4067.   82982.
  GW OUTFLOW                      1500.    1400.    1300.    1250.    1500.    1500.    1500.    1500.    2000.    1800.    1500.    1500.   18250.
  CHANGE IN GW STORAGE             -83.    -131.     -75.     -25.     593.     549.    -258.    -171.     762.     204.     184.    -275.    1275.
  SURFACE OUTFLOW                 5204.    4832.    5013.    4818.    5620.    3962.    8293.   10223.    7897.    1811.    2943.    2842.   63457.
  GAGED SURFACE OUTFLOW           4530.    4380.    4730.    4780.    5320.    4580.    7920.    9720.    7380.    1800.    3390.    3650.   62180.
  DIFFERENCE (COMP-GAGED)          674.     452.     283.      38.     300.    -618.     373.     503.     517.      11.    -447.    -808.    1277.
SUM OF ABSOLUTE DIFFERENCES =              5024.

                                                  CONSUMPTIVE USE CALCULATIONS
     YEAR 1969                      OCT      NOV      DEC      JAN      FEB      MAR      APR      MAY      JUN      JUL      AUG      SEP   ANNUAL
INPUT PRECIPITATION                1.90      .62     2.36     1.34     2.66     2.77     2.00     1.37     3.22      .11     3.44      .32    22.11
AVERAGE TEMPERATURE               49.90    39.60    21.50    19.70    29.40    40.30    41.70    54.30    62.70    72.90    66.10    59.00    46.42
BLANEY-CRIDDLE 'F'                 3.86     2.63     1.38     1.30     1.96     3.34     3.74     5.47     6.38     7.56     6.36     4.97    48.95
AGRICULTURAL CROPS
 1 ALFALF UNIT USE (IN.)           1.89      .78      .27      .25      .43     1.11     1.51     3.93     5.85     7.80     5.49     3.44    32.76
 1 ALFALF USE (ACRE-FT)            418.     173.      60.      55.      95.     246.     334.     871.    1296.    1728.    1215.     762.    7252.
 2 PASTRE UNIT USE (IN.)           1.70      .72      .24      .21      .39     1.04     1.31     3.49     4.87     6.66     4.60     3.05    28.48
 2 PASTRE USE (ACRE-FT)            258.     110.      37.      33.      59.     157.     199.     530.     740.    1012.     730.     464.    4330.
 3 HAY    UNIT USE (IN.)           1.80      .75      .26      .23      .41     1.06     1.43     3.73     5.36     7.23     5.17     3.23    30.67
 3 HAY    USE (ACRE-FT)             32.      13.       5.       4.       7.      19.      26.      67.      96.     130.      93.      58.     550.
 4 GRAIN  UNIT USE (IN.)            .47      .28      .12      .11      .17      .36     1.13     4.04     6.25     5.23     2.11      .67    20.93
 4 GRAIN  USE (ACRE-FT)             90.      55.      23.      22.      33.      69.     217.     777.    1203.    1007.     406.     128.    4029.
 5 CORN   UNIT USE (IN.)           2.10      .29      .12      .11      .17      .36      .33     2.05     3.59     6.66     5.59     3.83    25.20
 5 CORN   USE (ACRE-FT)             44.       6.       3.       2.       4.       8.       7.      43.      76.     140.     118.      81.     530.
 6 BEETS  UNIT USE (IN.)           2.16      .28      .12      .11      .17      .36      .33     1.98     3.69     6.87     5.70     3.90    25.68
 6 BEETS  USE (ACRE-FT)             17.       2.       0.       0.       1.       3.       3.      15.      29.      54.      44.      30.     200.
 7 TRUCK  UNIT USE (IN.)            .47      .28      .12      .11      .17      .36      .33     1.91     3.54     5.94     4.01      .67    17.92
 7 TRUCK  USE (ACRE-FT)              6.       4.       1.       1.       2.       4.       4.      24.      44.      74.      50.       8.     224.
 8 UR-IDL UNIT USE (IN.)            .74      .29      .10      .10      .15      .38      .50     1.30     1.92     2.79     2.06     1.37    11.71
 8 UR-IDL USE (ACRE-FT)            115.      45.      16.      15.      23.      59.      78.     201.     296.     431.     318.     211.    1807.
  CROPLAND P.C.U.                  980.     408.     145.     134.     224.     566.     867.    2528.    3780.    4575.    2973.    1743.   18922.
ACTUAL CROPLAND C.U.    O          980.     408.     145.     134.     224.     566.     867.    2528.    3780.    4575.    2973.    1743.   18922.
WET LAND PHREATOPHYTES
 1 VRDNPH UNIT USE (IN.)           3.27     1.44      .54      .48      .88     2.14     2.60     5.78     8.07    11.31     8.18     5.41    50.09
 1 VRDNPH USE (ACRE-FT)             59.      26.      10.       9.      16.      38.      47.     104.     145.     204.     147.      97.     902.
 2 DNSPHY UNIT USE (IN.)           2.91     1.25      .46      .39      .77     1.91     2.37     5.30     7.43    10.31     7.44     4.84    45.38
 2 DNSPHY USE (ACRE-FT)             86.      37.      14.      12.      23.      56.      70.     156.     219.     304.     219.     143.    1337.
 3 MEDPHY UNIT USE (IN.)           2.52     1.07      .39      .31      .65     1.69     2.15     4.82     6.79     9.31     6.65     4.28    40.63
 3 MEDPHY USE (ACRE-FT)             74.      31.      11.       9.      19.      49.      63.     141.     198.     272.     194.     125.    1186.
 4 LTPHRY UNIT USE (IN.)           1.97      .89      .32      .26      .62     1.53     1.83     3.76     5.37     7.02     5.12     3.34    31.72
 4 LTPHRY USE (ACRE-FT)             62.      28.      10.       8.      19.      48.      57.     117.     158.     219.     160.     104.     990.
 5 VLTPHY UNIT USE (IN.)            .74      .29      .10      .10      .15      .38      .50     1.30     1.92     2.79     2.06     1.37    11.71
 5 VLTPHY USE (ACRE-FT)             19.       7.       3.       2.       4.      10.      13.      33.      49.      71.      52.      35.     298.
  POTENTIAL WETLAND CU             299.     129.      47.      43.      80.     202.     249.     551.     769.    1069.     772.     504.    4713.
ACTUAL WETLAND C.U.     O          299.     129.      47.      43.      80.     202.     249.     551.     769.    1069.     772.     504.    4713.
RESERVOIR EVAPORATION   O          2.91     1.25      .46      .39      .77     1.91     2.37     5.30     7.43    10.31     7.44     4.84    45.38
RESERVOIR EVAPORATION   O           90.      39.      14.      12.      24.      59.      74.     164.     230.     320.     231.     150.    1407.

                        1968  FLOW VALUES IN CFS FOR WATER QUALITY MODEL
QI     1968                       57.41    58.92    60.99    56.60    76.53    89.12   116.46   224.92   142.51    48.79    59.04    52.94    87.03
QS     1968                        1.02      .48     1.35     2.61      .53      .33     4.66     4.85    20.75     3.81     1.99    14.36     4.70
QGI    1968                       25.00    17.28    12.46    12.56    17.51    16.01    11.98    12.75    17.21    12.36    19.34    19.58    16.15
QD     1968                        9.76     5.04     4.88     4.88     5.43     4.88     5.94    75.35   124.53   150.92    80.98    62.00    44.74
QIR    1968                         .00      .00      .00      .00      .03      .00      .00      .00     3.50     4.24     2.20     2.45     1.04
QEF    1968                       10.00    10.03    10.03    10.99    11.03    14.00    10.00    10.00    10.00    10.00    10.00    10.00    16.50
QO     1968                       84.63    81.70    81.53    78.36   101.19    64.44   139.37   166.27   132.71    29.45    47.86    47.76    87.65
QGFLO  1968                       73.67    73.61    76.93    77.74    95.79    74.49   133.10   158.08   124.02    29.27    55.13    61.34    85.89
QDIFF  1968                       10.96     7.59     4.63      .62     5.40   -10.05     6.27     8.19     8.69      .17    -7.27   -13.58     1.76
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Figure G-6. Continued.

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                                   10-1076  LITTLE BEAR RIVER BELOW PARADISE AT WELLSVILLE, UTAH
ITEM--YEAR MEAN                 OCT      NOV      DEC      JAN      FEB      MAR      APR      MAY      JUN      JUL      AUG      SEP    ANNUAL
MEASURED INFLOW            I   2890.    2990.    3235.    3025.    3390.    5415.    7925.   20065.   12410.    3300.    3770.    3280.   71695.
MEASURED IMPORTS           I      0.       0.       0.       0.       0.       0.       0.     855.    2586.    2988.    1773.    1225.    9429.
UNMEASURED INFLOW          I   2489.    2157.    2004.    2135.    2363.    2317.    1671.    1492.    1617.     286.    1250.    2231.   22013.
  UNMEASURED SURFACE IN          55.      26.      80.     158.      24.      21.     304.     380.    1519.     286.     129.     893.    3874.
  GROUNDWATER INFLOW           2434.    2132.    1924.    1977.    2339.    2296.    1367.    1112.      99.       0.    1121.    1339.   18139.
  RESERVOIR STORAGE            8100.    9390.   10285.   10395.   10395.   13990.   14535.   15665.   15045.   11185.    9990.   10395.   10395.
RESERVOIR PRECIPITATION I        36.      30.      63.      46.      53.      94.     100.      36.     105.       7.      53.       7.     631.
RESERVOIR EVAPORATION   0        86.      40.      15.      15.      25.      55.      75.     162.     222.     321.     265.     166.    1447.
CHANGE IN RES STORAGE   0       820.    1290.     895.     110.       0.    3595.     545.    1130.    -620.   -3860.   -1195.     405.    3115.
  SURFACE RETURN FLOW             0.       0.       0.       0.       0.       0.       0.       0.     203.     282.     176.     171.     831.
  GROUNDWATER TO SURFACE       1138.     833.     699.     743.     703.     950.     488.     472.     993.     846.    1604.    1399.   10868.
  M AND I RETURN FLOW           615.     595.     645.     676.     611.     768.     773.     676.     714.     676.     676.     654.    8082.
  USEABLE SURFACE WATER       11928.   12534.   14098.   14918.   15151.   17588.   23506.   36858.   33974.   23111.   19101.   17453.  240219.
EXPORTS                 0       323.       0.       0.       0.       0.       0.       0.    1216.     977.    3374.    2124.    1427.    9441.
  M AND I DIVERSION             150.     150.     150.     150.     150.     150.     150.     150.     150.     421.     150.     150.    2071.
M AND I NET USE         0      -465.    -445.    -495.    -526.    -461.    -618.    -623.    -526.    -564.    -255.    -526.    -504.   -6011.
  CROPLAND DIVERSIONS           150.       0.       0.       0.       0.       0.       0.    1242.    5919.    6292.    4179.    2808.   20591.
  AMOUNT TO ROOT ZONE            45.       0.       0.       0.       0.       0.       0.     373.    1776.    1888.    1254.     842.    6177.
  CROPLAND RETURN FLOW          105.       0.       0.       0.       0.       0.       0.     870.    4143.    4404.    2926.    1966.   14414.
CROPLAND PRECIPITATION  I       908.     752.    1586.    1158.    1325.    2366.    2518.     904.    2643.     187.    1345.     172.   15865.
SNOW STORAGE ADDED      0         0.       0.    1586.    1158.    1325.       0.       0.       0.       0.       0.       0.       0.    4069.
  ACCUM SNOW STORAGE              0.       0.       0.    1586.    2145.    1349.       0.       0.       0.       0.       0.       0.       0.
  SNOW MELT             I         0.       0.       0.     599.    2122.    1349.       0.       0.       0.       0.       0.       0.    4069.
  ROOT ZONE SUPPLY              953.     752.       0.     599.    2122.    3715.    2518.    1277.    4418.    2075.    2599.    1014.   22042.
  CROPLAND P.C.U.               940.     424.     149.     164.     234.     531.     881.    2493.    3638.    4590.    3419.    1929.   19392.
  RZ SUPPLY-P.C.U.               13.     328.    -149.     435.    1888.    3184.    1637.   -1216.     781.   -2515.    -820.    -915.    2650.
ACCUM SOIL MOISTURE   I-0      4275.    4788.    5116.    4966.    5402.    7290.   10737.   11628.   10412.   11193.    8677.    7857.    6942.
  CONS. USE DEFICIT               0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
ACTUAL CROPLAND C.U.    0       940.     424.     149.     164.     234.     531.     881.    2493.    3638.    4590.    3419.    1929.   19392.
  INTERFLOW ADDED                 0.       0.       0.       0.       0.     136.     346.       0.       0.       0.       0.       0.     482.
  GW RETURN FLOW                105.       0.       0.       0.       0.       0.       0.     870.    3940.    4123.    2750.    1795.   13582.
ACCUM INTERFLOW       I-0      3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.    3500.
  INTERFLOW TO SURFACE         1138.     833.     699.     743.     703.     950.     488.     472.     993.     846.    1604.    1399.   10868.
  INTERFLOW SUPPLY TO WL        176.      73.       0.       9.     411.     257.       0.     284.    1821.    2051.    1043.     510.    6636.
WETLAND PRECIPITATION   I       155.     129.     271.     198.     227.     405.     431.     155.     452.      32.     230.      29.    2713.
SNOW STORAGE ADDED      0         0.       0.     271.     198.     227.       0.       0.       0.       0.       0.       0.       0.     696.
  ACCUM SNOW STORAGE              0.       0.       0.     271.     367.     231.       0.       0.       0.       0.       0.       0.       0.
SNOW MELT               I         0.       0.       0.     102.     363.     231.       0.       0.       0.       0.       0.       0.     696.
  TOTAL SUPPLY TO WL           1228.     994.     799.     799.    1696.    1972.    1448.    1409.    4049.    4149.    3352.    1892.   52662.
  POTENTIAL WETLAND CU          287.     135.      49.      49.      84.     189.     253.     544.     740.    1073.     888.     558.    4848.
  TSWL-WL PCU                    45.      68.     -49.      62.     690.     703.     177.    -105.    1532.    1011.     384.     -19.    4501.
ACCUM WL SOIL MOIST   I-0      1600.    1549.    1594.    1546.    1561.    1600.    1600.    1600.    1443.    1600.    1600.    1600.    1581.
  WETLAND DEFICIT                 0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
ACTUAL WETLAND C.U.     0       287.     135.      49.      49.      84.     189.     253.     544.     740.    1073.     888.     558.    4848.
  WETLAND SURFACE OUTFLOW         0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
  WETLAND ADDITION TO GW         96.      22.       0.      47.     651.     703.     177.      52.    1376.    1011.     384.       0.    4519.
  INTERFLOW TO GW              1225.    1225.    1225.    1225.    1225.    1225.    1225.    1225.    1225.    1225.    1225.    1225.   14700.
  TOTAL GW ADDED               1321.    1247.    1225.    1272.    1876.    1928.    1402.    1277.    2601.    2236.    1609.    1225.   19219.
OUTFLOW + CHANGE IN GW  0      4526.    4241.    4888.    5645.    6482.    5376.   10223.   19862.   14484.    4074.    4267.    3898.   87965.
  GW OUTFLOW                   1350.    1300.    1250.    1225.    1500.    1500.    1500.    1500.    2000.    1800.    1500.    1500.   17925.
  CHANGE IN GW STORAGE          -29.     -53.     -25.      47.     376.     428.     -98.    -223.     601.     436.     109.    -275.    1294.
  SURFACE OUTFLOW              3205.    2994.    3663.    4373.    4606.    3448.    4821.   18585.   11883.    1839.    2658.    2673.   68746.
  GAGED SURFACE OUTFLOW        3060.    2795.    3550.    4340.    4510.    3595.    4950.   18315.   11920.    1720.    2705.    2920.   68380.
  DIFFERENCE (COMP-GAGED)       145.     199.     113.      33.      96.    -147.     129.     270.     -37.     119.     -47.    -247.     366.
SUM OF ABSOLUTE DIFFERENCES =           4366.

                                                   CONSUMPTIVE USE CALCULATIONS
      YEAR MEAN                 OCT      NOV      DEC      JAN      FEB      MAR      APR      MAY      JUN      JUL      AUG      SEP    ANNUAL
INPUT PRECIPITATION            1.75     1.45     3.05     2.23     2.55     4.55     4.84     1.99     5.08      .36     2.61      .33    30.80
AVERAGE TEMPERATURE           49.10    43.15    22.15    24.15    30.65    39.40    41.95    54.30    61.70    73.00    70.00    61.45    47.31
BLANEY-CRIDDLE "F"             3.80     2.67     1.42     1.59     2.35     3.26     3.76     5.44     6.28     7.57     6.73     5.17    49.75
AGRICULTURAL CROPS
 1 ALFALF UNIT USE (IN.)       1.81      .81      .28      .31      .45     1.04     1.53     3.88     5.63     7.83     6.31     3.81    33.69
 1 ALFALF USE (ACRE-FT)        401.     187.      61.      68.      99.     231.     339.     859.    1247.    1734.    1397.     843.    7459.
 2 PASTRE UNIT USE (IN.)       1.63      .75      .25      .26      .41      .97     1.33     3.44     4.69     6.68     5.52     3.38    29.31
 2 PASTRE USE (ACRE-FT)        248.     114.      38.      40.      62.     148.     202.     523.     712.    1016.     839.     514.    4455.
 3 HAY    UNIT USE (IN.)       1.73      .78      .26      .29      .43     1.00     1.45     3.68     5.16     7.26     5.94     3.57    31.56
 3 HAY    USE (ACRE-FT)         31.      14.       5.       5.       8.      18.      26.      66.      93.     130.     107.      64.     566.
 4 GRAIN  UNIT USE (IN.)        .45      .29      .12      .14      .18      .34     1.15     3.98     6.01     5.24     2.43      .74    21.06
 4 GRAIN  USE (ACRE-FT)         86.      57.      24.      27.      34.      65.     221.     766.    1158.    1010.     467.     142.    4056.
 5 CORN   UNIT USE (IN.)       2.32      .29      .12      .14      .18      .34      .34     2.32     3.46     6.68     6.43     4.23    26.25
 5 CORN   USE (ACRE-FT)         42.       5.       3.       3.       4.       7.       7.      43.      73.     141.     135.      89.     553.
 6 BEETS  UNIT USE (IN.)       2.08      .29      .12      .14      .18      .34      .34     1.96     3.55     6.90     6.55     4.31    26.75
 6 BEETS  USE (ACRE-FT)         16.       2.       0.       1.       1.       3.       3.      15.      28.      54.      51.      34.     209.
 7 TRUCK  UNIT USE (IN.)        .45      .29      .12      .14      .18      .34      .34     1.89     3.41     5.96     4.61      .74    18.47
 7 TRUCK  USE (ACRE-FT)          6.       4.       2.       2.       2.       4.       4.      24.      43.      74.      58.       9.     230.
 8 UR-IDL UNIT USE (IN.)        .71      .30      .11      .12      .15      .36      .51     1.28     1.85     2.80     2.37     1.51    12.08
 8 UR-IDL USE (ACRE-FT)        110.      47.      16.      18.      24.      56.      79.     198.     285.     432.     365.     234.    1664.
  CROPLAND P.C.U.              940.     424.     149.     164.     234.     531.     881.    2493.    3638.    4590.    3419.    1929.   19392.
ACTUAL CROPLAND C.U.    0      940.     424.     149.     164.     234.     531.     881.    2493.    3638.    4590.    3419.    1929.   19392.
WET LAND PHREATOPHYTES
 1 VRDNPH UNIT USE (IN.)       3.13     1.49      .56      .59      .92     2.00     2.65     5.70     7.76    11.35     9.40     5.98    51.55
 1 VRDNPH USE (ACRE-FT)         56.      27.      10.      11.      17.      36.      48.     103.     140.     204.     169.     108.     928.
 2 DNSPHY UNIT USE (IN.)       2.79     1.30      .48      .48      .80     1.79     2.41     5.23     7.15    10.34     8.55     5.36    46.69
 2 DNSPHY USE (ACRE-FT)         82.      38.      14.      14.      24.      53.      71.     154.     211.     305.     252.     158.    1376.
 3 MEDPHY UNIT USE (IN.)       2.42     1.12      .40      .38      .68     1.58     2.18     4.76     6.53     9.34     7.64     4.74    41.77
 3 MEDPHY USE (ACRE-FT)         71.      33.      12.      11.      20.      46.      64.     139.     191.     273.     223.     138.    1220.
 4 LTPHRY UNIT USE (IN.)       1.89      .93      .33      .32      .64     1.44     1.86     3.71     4.88     7.04     5.88     3.69    32.61
 4 LTPHRY USE (ACRE-FT)         59.      29.      10.      10.      20.      45.      58.     116.     152.     220.     184.     115.    1017.
 5 VLTPHY UNIT USE (IN.)        .71      .30      .11      .12      .15      .36      .51     1.28     1.85     2.80     2.37     1.51    12.08
 5 VLTPHY USE (ACRE-FT)         18.       8.       3.       3.       4.       9.      13.      33.      47.      71.      60.      39.     308.
  POTENTIAL WETLAND CU         287.     135.      49.      49.      84.     189.     253.     544.     740.    1073.     888.     558.    4848.
ACTUAL WETLAND C.U.     0      287.     135.      49.      49.      84.     189.     253.     544.     740.    1073.     888.     558.    4848.
RESERVOIR EVAPORATION   0      2.79     1.30      .48      .48      .80     1.79     2.41     5.23     7.15    10.34     8.55     5.36    46.69
RESERVOIR EVAPORATION   0       86.      40.      15.      15.      25.      55.      75.     162.     222.     321.     265.     166.    1447.

                            MEAN  FLOW VALUES IN CFS FOR WATER QUALITY MODEL
QI     MEAN              47.00    50.25    52.61    49.20    61.04    88.07   133.18   326.33   208.56    53.67    61.31    55.12     99.03
QS     MEAN                .89      .44     1.30     2.57      .43      .34     5.11     6.19    25.52     4.65     2.09    15.00      5.35
QGI    MEAN              18.51    14.03    11.37    12.08    12.66    15.45     8.20     7.68    16.69    13.76    26.08    23.51     15.61
QD     MEAN              10.13     2.52     2.44     2.44     2.73     2.44     2.52    42.42   118.41   164.05   104.96    73.69     44.34
QIR    MEAN                .00      .03      .00      .00      .03      .00      .00      .00     3.41     4.58     2.85     2.87      1.15
QEF    MEAN              10.00    10.03    10.53    10.99    11.03    12.50    13.00    11.00    12.00    11.00    11.00    11.00     11.16
QO     MEAN              52.12    50.31    59.57    71.12    82.93    56.07   148.24   302.25   199.70    29.90    43.23    44.92     94.96
QGFLO  MEAN              49.77    46.97    57.74    71.58    81.21    58.47   150.41   297.86   200.32    27.97    43.99    49.07     94.45
QDIFF  MEAN               2.35     3.34     1.83      .54     1.72    -2.39    -2.17     4.39     -.62     1.93     -.77    -4.16       .51
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Figure G-6. Continued.

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                                    10-1076  LITTLE BEAR RIVER BELOW PARADISE AT WELLSVILLE, UTAH
ITEM--YEAR SDEV                 OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP   ANNUAL
MEASURED INFLOW           I    905.    721.    728.    643.   1216.     92.   1407.   8818.   5558.    424.    198.    184.   12282.
MEASURED IMPORTS          I      0.      0.      0.      0.      0.      0.      0.   1213.    309.    463.    523.    175.     358.
UNMEASURED INFLOW         I    515.    303.     99.     45.    610.    132.    211.    457.    428.     74.     85.    135.      52.
  UNMEASURED SURFACE IN         11.      4.      4.      3.      6.      1.     38.    116.    402.     74.      9.     54.     666.
  GROUNDWATER INFLOW           503.    300.     95.     42.    603.    130.    172.    340.     26.      0.     76.     81.     717.
  RESERVOIR STORAGE           3422.   1598.    276.    120.    120.    566.   1464.    138.    530.    559.    212.    304.     304.
RESERVOIR PRECIPITATION I       32.     15.     14.      6.     42.     12.     54.      9.      7.      6.     75.      4.      77.
RESERVOIR EVAPORATION   O        5.      2.      0.      4.      1.      5.      2.      3.     12.      1.     49.     23.      57.
CHANGE IN RES STORAGE   O     1287.   1824.   1322.    156.      0.    686.    898.   1598.    665.     28.    346.     92.    5013.
  SURFACE RETURN FLOW            0.      0.      0.      0.      0.      0.      0.      0.      8.     30.     57.     35.     114.
  GROUNDWATER TO SURFACE       565.    275.     95.     41.    381.     49.    317.    442.     44.    127.    587.    331.    1163.
  M AND I RETURN FLOW            0.      0.     43.      0.      0.    131.    252.     87.    168.     87.     87.     84.     678.
  USEABLE SURFACE WATER       6217.   4410.   2397.    962.   1767.    374.   1998.   8827.   5653.   1739.   1894.   1049.    5035.
EXPORTS                 O      457.      0.      0.      0.      0.      0.      0.   1154.     78.    305.    942.    617.    1089.
  M AND I DIVERSION            212.    212.    212.    212.    212.    212.    212.    212.    212.    171.    212.    212.    2162.
M AND I NET USE         O      212.    212.    255.    212.    212.     81.    465.    299.    340.     84.    299.    296.    2840.
  CROPLAND DIVERSIONS          212.      0.      0.      0.      0.      0.      0.   1497.    225.    665.   1356.    580.     666.
  AMOUNT TO ROOT ZONE           64.      0.      0.      0.      0.      0.      0.    449.     67.    199.    407.    174.     200.
  CROPLAND RETURN FLOW         148.      0.      0.      0.      0.      0.      0.   1048.    157.    465.    949.    406.     466.
CROPLAND PRECIPITATION  I      810.    369.    358.    160.   1058.    292.   1356.    232.    187.    143.   1891.    110.    1940.
SNOW STORAGE ADDED      O        0.      0.    358.    160.   1058.      0.      0.      0.      0.      0.      0.      0.    1257.
  ACCUM SNOW STORAGE             0.      0.      0.    358.   1745.   1318.      0.      0.      0.      0.      0.      0.       0.
  SNOW MELT             I        0.      0.      0.    847.    786.   1318.      0.      0.      0.      0.      0.      0.    1257.
  ROOT ZONE SUPPLY             874.    380.      0.    847.    786.   1026.   1356.    681.    120.    343.   1484.     64.    1741.
  CROPLAND P.C.U.               56.     23.      6.     43.     13.     49.     21.     49.    201.     21.    630.    262.     664.
  RZ SUPPLY-P.C.U.             818.    357.      6.    804.    799.    977.   1336.    632.    321.    322.   2114.    199.    2405.
ACCUM SOIL MOISTURE   I-O      671.   1489.   1132.   1138.    334.   1133.   1918.     93.    725.    403.     81.   2196.    2394.
  CONS. USE DEFICIT              0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.       0.
ACTUAL CROPLAND C.U.    O       56.     23.      6.     43.     13.     49.     21.     49.    201.     21.    630.    262.     664.
  INTERFLOW ADDED                0.      0.      0.      0.      0.    192.    490.      0.      0.      0.      0.      0.     682.
  GW RETURN FLOW               148.      0.      0.      0.      0.      0.      0.   1048.    150.    435.    892.    371.     352.
ACCUM INTERFLOW       I-O        0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.       0.
  INTERFLOW TO SURFACE         565.    275.     95.     41.    381.     49.    317.    442.     44.    127.    587.    331.    1163.
  INTERFLOW SUPPLY TO WL        87.     24.      0.      0.    223.     13.      0.    266.     80.    308.    381.    121.     116.
WETLAND PRECIPITATION   I      139.     65.     61.     27.    181.     50.    232.     49.     32.     25.    323.     19.     332.
SNOW STORAGE ADDED      O        0.      0.     61.     27.    181.      0.      0.      0.      0.      0.      0.      0.     215.
  ACCUM SNOW STORAGE             0.      0.      0.     61.    179.    225.      0.      0.      0.      0.      0.      0.       0.
SNOW MELT               I        0.      0.      0.    145.    134.    225.      0.      0.      0.      0.      0.      0.     215.
  TOTAL SUPPLY TO WL          1288.   1121.   1130.    983.   1351.   1539.   1458.   1405.   2513.   2941.   2941.   1916.   20573.
  POTENTIAL WETLAND CU          17.      7.      2.     13.      5.     17.      6.     11.     41.      5.    164.     76.     191.
  TSWL-WL PCU                  209.     33.      2.    132.    362.    171.    226.    295.      7.    328.    106.     26.     407.
ACCUM WL SOIL MOIST   I-O        0.     73.      8.     10.     55.      0.      0.      0.    222.      0.      0.      0.      26.
  WETLAND DEFICIT                0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.       0.
ACTUAL WETLAND C.U.     O       17.      7.      2.     13.      5.     17.      6.     11.     41.      5.    164.     76.     191.
  WETLAND SURFACE OUTFLOW        0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.       0.
  WETLAND ADDITION TO GW       136.     31.      0.     66.    307.    171.    226.     73.    229.    328.    106.      0.     432.
  INTERFLOW TO GW                0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.       0.
  TOTAL GW ADDED               136.     31.      0.     66.    307.    171.    226.     73.    229.    328.    106.      0.     432.
OUTFLOW + CHANGE IN GW  R     2963.   2631.   1909.    563.   1741.    898.    973.  11752.   5409.    368.    509.    240.    7047.
  GW OUTFLOW                   212.    141.     71.     35.      0.      0.      0.      0.      0.      0.      0.      0.     460.
  CHANGE IN GW STORAGE          76.    110.     71.    102.    307.    171.    226.     73.    229.    328.    106.      0.      27.
  SURFACE OUTFLOW             2828.   2600.   1909.    629.   1434.    727.    747.  11825.   5637.     40.    403.    240.    7479.
  GAGED SURFACE OUTFLOW       2079.   2242.   1669.    622.   1146.   1393.   1457.  12155.   6421.    113.    969.   1032.    8768.
  DIFFERENCE (COMP-GAGED)      749.    358.    240.      7.    289.    666.    710.    330.    783.    153.    566.    793.    1289.
SUM OF ABSOLUTE DIFFERENCES =          1355.

                                              CONSUMPTIVE USE CALCULATIONS
      YEAR SDEV                 OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP   ANNUAL
INPUT PRECIPITATION            1.67    1.09    1.66    1.16    2.16    2.26    3.16    1.37    2.46     .50    3.13     .43    15.04
AVERAGE TEMPERATURE            1.13     .78     .92    6.29    1.77    1.27     .35     .42    1.41     .14    5.52    3.46     1.25
BLANEY-CRIDDLE "F"              .09     .05     .06     .42     .12     .11     .03     .34     .14     .01     .53     .29     1.13
AGRICULTURAL CROPS
 1 ALFALF UNIT USE (IN.)        .11     .04     .01     .08     .03     .10     .04     .08     .31     .04    1.16     .52     1.32
 1 ALFALF USE (ACRE-FT)         24.     13.      3.     18.      6.     21.      8.     17.     69.      8.    258.    115.     293.
 2 PASTRE UNIT USE (IN.)        .10     .04     .01     .07     .02     .09     .03     .07     .26     .03    1.02     .46     1.17
 2 PASTRE USE (ACRE-FT)         15.      6.      2.     13.      4.     14.      5.     10.     39.      5.    155.     70.     178.
 3 HAY    UNIT USE (IN.)        .10     .04     .01     .07     .02     .09     .03     .07     .29     .03    1.10     .49     1.25
 3 HAY    USE (ACRE-FT)          2.      0.      0.      1.      0.      2.      0.      1.      5.      0.     20.      9.      22.
 4 GRAIN  UNIT USE (IN.)        .03     .02     .00     .04     .01     .03     .03     .08     .33     .02     .45     .10      .20
 4 GRAIN  USE (ACRE-FT)          5.      3.      0.      7.      2.      6.      5.     15.     64.      5.     86.     19.      38.
 5 CORN   UNIT USE (IN.)        .12     .02     .00     .04     .01     .03     .00     .04     .19     .03    1.19     .58     1.49
 5 CORN   USE (ACRE-FT)          3.      0.      0.      0.      0.      0.      0.      0.      4.      0.     25.     12.      31.
 6 BEETS  UNIT USE (IN.)        .12     .02     .00     .04     .01     .03     .00     .04     .20     .03    1.21     .59     1.51
 6 BEETS  USE (ACRE-FT)          0.      0.      0.      0.      0.      0.      0.      0.      2.      0.      9.      5.      12.
 7 TRUCK  UNIT USE (IN.)        .03     .02     .00     .04     .01     .03     .00     .04     .19     .03     .85     .10      .77
 7 TRUCK  USE (ACRE-FT)          0.      0.      0.      0.      0.      0.      0.      0.      2.      0.     11.      1.      10.
 8 UR-IDL UNIT USE (IN.)        .04     .02     .00     .03     .00     .03     .01     .03     .10     .01     .44     .21      .52
 8 UR-IDL USE (ACRE-FT)          7.      3.      0.      5.      1.      5.      2.      4.     16.      2.     67.     32.      81.
  CROPLAND P.C.U.               56.     23.      6.     43.     13.     49.     21.     49.    201.     21.    630.    262.     664.
ACTUAL CROPLAND C.U.    O       56.     23.      6.     43.     13.     49.     21.     49.    201.     21.    630.    262.     664.
WET LAND PHREATOPHYTES
 1 VRDNPH UNIT USE (IN.)        .19     .08     .02     .15     .05     .18     .06     .11     .43     .05    1.73     .81     2.06
 1 VRDNPH USE (ACRE-FT)          3.      1.      0.      3.      0.      3.      1.      2.      8.      0.     31.     15.      37.
 2 DNSPHY UNIT USE (IN.)        .17     .07     .02     .13     .05     .16     .06     .10     .40     .05    1.58     .73     1.84
 2 DNSPHY USE (ACRE-FT)          5.      2.      0.      4.      1.      5.      2.      3.     12.      1.     46.     21.      54.
 3 MEDPHY UNIT USE (IN.)        .14     .06     .02     .10     .04     .15     .05     .09     .36     .04    1.41     .64     1.62
 3 MEDPHY USE (ACRE-FT)          4.      2.      0.      3.      1.      4.      1.      3.     11.      1.     41.     19.      47.
 4 LTPHRY UNIT USE (IN.)        .11     .05     .01     .08     .04     .13     .04     .37     .27     .03    1.08     .50     1.26
 4 LTPHRY USE (ACRE-FT)          4.      2.      0.      3.      1.      4.      1.      2.      8.      0.     34.     16.      39.
 5 VLTPHY UNIT USE (IN.)        .04     .02     .00     .03     .00     .03     .01     .03     .10     .01     .44     .21      .52
 5 VLTPHY USE (ACRE-FT)          1.      0.      0.      0.      0.      0.      0.      0.      3.      0.     11.      5.      13.
  POTENTIAL WETLAND CU          17.      7.      2.     13.      5.     17.      6.     11.     41.      5.    164.     76.     191.
ACTUAL WETLAND C.U.     O       17.      7.      2.     13.      5.     17.      6.     11.     41.      5.    164.     76.     191.
RESERVOIR EVAPORATION   O       .17     .07     .02     .13     .05     .16     .06     .10     .40     .05    1.58     .73     1.84
RESERVOIR EVAPORATION   O        5.      2.      0.      4.      1.      5.      2.      3.     12.      1.     49.     23.      57.

                            SDEV  FLOW VALUES IN CFS FOR WATER QUALITY MODEL
QI     SDEV           14.72   12.12   11.84   10.46   21.90    1.49   23.65  143.40   93.40    6.90    3.22    3.09   16.97
QS     SDEV             .18     .06     .06     .05     .11     .02     .64    1.89    6.75    1.20     .14     .91     .92
QGI    SDEV            9.18    4.63    1.55     .67    6.86     .79    5.33    7.18     .73    2.07    9.54    5.56    1.61
QD     SDEV           14.33    3.56    3.45    3.45    3.82    3.45    3.56   46.56    8.65   18.56   40.81   23.67    5.41
QIR    SDEV             .00     .00     .00     .00     .00     .00     .00     .00     .13     .48     .93     .59     .16
QEF    SDEV             .00     .00     .73     .00     .00    2.13    4.24    1.41    2.83    1.41    1.41    1.41     .98
QO     SDEV           45.99   43.69   31.05   10.23   25.43   11.83   12.55  192.31   94.78     .64    6.55    4.02   10.33
QGFLO  SDEV           33.81   37.67   27.14   10.12   20.63   22.65   24.48  197.68  107.90    1.84   15.75   17.35   12.11
QDIFF  SDEV           12.18    6.02    3.91     .11    5.20   10.83   11.93    5.37   13.16    2.48    9.20   13.32    1.78
```

Figure G-6. Continued.

APPENDIX H

STATISTICAL ANALYSIS OF LITTLE BEAR RIVER WATER QUALITY DATA

This study was made to determine the degree of correlation which exists between the water quality parameters measured during the project. The data analyzed were from three stations on the Little Bear River obtained at weekly intervals over a period of two and one-half years. Stations S-12.5 (S-12.7), S-15.2, and S-27.5 were selected for analysis because streamflow data are available at these locations and because they represent the lower, middle, and upper reaches of the river, respectively.

The study was conducted in two phases: (1) a broad spectrum search for statistical correlation and (2) a search for specific models relating water quality parameters.

The broad spectrum search

The objective of this phase of the study was to examine the whole spectrum of measured water quality variables for significant and meaningful intercorrelation. The correlation coefficient, r_{ij}, was used as the statistic to measure the intercorrelation between any two water quality variables.

$$r_{ij} = \frac{\Sigma(X_i - \bar{X}_i)\,(X_j - \bar{X}_j)}{\{[\Sigma(X_i - \bar{X}_i)]^2 \cdot [\Sigma(X_j - \bar{X}_j)]^2\}^{1/2}} \qquad \text{. . . . . (H-1)}$$

where

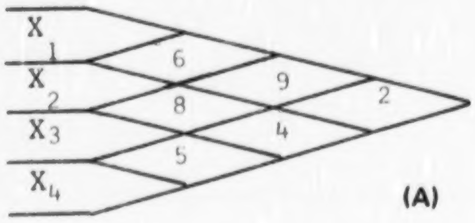
X_i denotes variable number i and X_j denotes variable j.

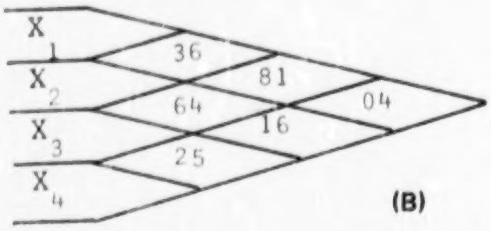
Values of the correlation coefficient may range from -1.0 to +1.0, indicating perfect negative and perfect positive correlation, respectively.

The square of the correlation coefficient is referred to as the coefficient of determination and indicates the proportion of the total information about one variable that is made available by knowledge of the value of another variable. A value of r_{ij} equal to .80 means that variable X_j contains 64 percent of the same information that variable X_i contains. A convenient way to display the intercorrelation existing among many variables is by a triangular table of correlation coefficients with the correlation between two variables in the block formed by the intersection of diagonals from the two variables in question. A typical display of the correlation coefficients for four variables and its corresponding table of coefficients of determination is shown in Table H-1(A) where

$$\begin{bmatrix} r_{12} = .6, \\ r_{13} = .9, \\ r_{14} = .2, \\ r_{23} = .8, \\ r_{24} = .4, \\ r_{34} = .5. \end{bmatrix}$$

Table H-1. Example of of correlation coefficient table (A) and corresponding table of coefficients of determination (B).





The corresponding table of coefficients of determination is given in Table H-1(B). The Venn diagram of Figure H-1 is a useful aid in the visualization of the application of the coefficients of determination. The area of the rectangle represents the total information in X_2 (r_{22}^2 = 1.00). The area of the solid circle represents the proportion of information common to X_2 and X_3 or 64 percent (r_{23} = .8). The coefficient of determination between X_2 and X_1, the area of the dashed circle, is .36, but this 36 percent is not all new information about X_2, and 81 percent of it is contained in X_3 (r_{13}^2 = .81). Similarly, r_{24}^2 is shown as the area of the dotted circle in the diagram with one fourth of the 16 percent being information also contained in X_3 (r_{34}^2 = .25).

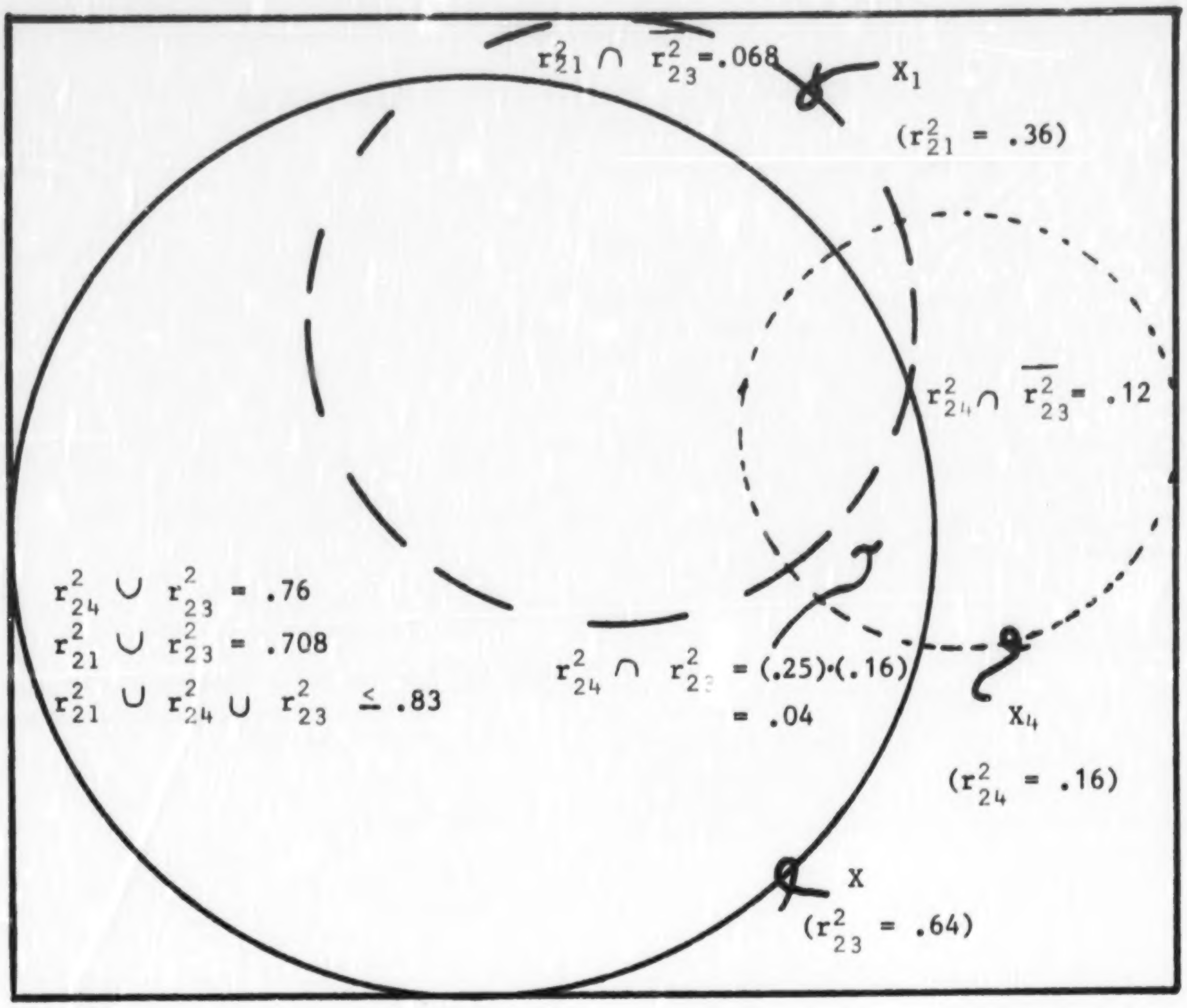

$r_{21}^2 \cap r_{23}^2 = .068$
X_1
$(r_{21}^2 = .36)$
$r_{24}^2 \cap \overline{r_{23}^2} = .12$
$r_{24}^2 \cup r_{23}^2 = .76$
$r_{21}^2 \cup r_{23}^2 = .708$
$r_{21}^2 \cup r_{24}^2 \cup r_{23}^2 \leq .83$
$r_{24}^2 \cap r_{23}^2 = (.25)\cdot(.16)$
$= .04$
X_4
$(r_{24}^2 = .16)$
X
$(r_{23}^2 = .64)$

Figure H-1. Venn diagram for a four variable system with X_2 as the dependent variable.

It is clear that any linear model used to explain variations in X_2 in terms of the other variables should include X_3. Although X_1 alone explains far more of the variation in X_2 than does X_4 alone; in combination with X_3 X_4 provides more information than X_1. This is shown in Figure H-1 by comparing the union of r_{23}^2 and r_{24}^2 $(r_{23}^2 \cup r_{24}^2)$ with the union of r_{23}^2 and r_{21}^2 $(r_{23}^2 \cup r_{21}^2)$. The model $X_2 = a+bX_3+cX_4+\varepsilon$ would explain 76 percent of the total variation in X_2, while the model $X_2 = a+bX_3+cX_1+$ would explain only 71 percent. The three variable model $X_2 = a+bX_3+cX_4+dX_1+$ could explain up to 83 percent of this variation. Statistical tests may be applied to determine whether the increase in variation explained by a model is statistically significant. Judgment must be exercised, however, to assure that the model thus developed has physical significance.

The 25 variables listed in Table 1 were included in the original set of water quality parameters analyzed. With the exception of Date, Time, Distance, and Total meq., these variables are self explanatory. Two-term transformations of date and time were used in regression models to obtain the correlation coefficient for each water quality parameter with date and time of sampling. The regression models used were

$$X = a + b_1 \cdot \mathrm{Sin}\left(\frac{2\pi}{365} \cdot \mathrm{JDAY}\right) + b_2 \cdot \mathrm{Cos}\left(\frac{2\pi}{365} \cdot \mathrm{JDAY}\right) + \varepsilon \quad . \; . \quad \text{(H-2)}$$

and

$$X = a + b_1 \cdot \mathrm{Sin}\left(\frac{2\pi}{24} \cdot \mathrm{TIME}\right) + b_2 \cdot \mathrm{Cos}\left(\frac{2\pi}{24} \cdot \mathrm{TIME}\right) + \varepsilon \quad . \; . \quad \text{(H-3)}$$

in which

X is the water quality parameter
JDAY is the consecutive day of the year
TIME is time of day

The multiple correlation coefficients of these models were taken as the correlation coefficient of the parameter being studied with date and time, respectively. All variables were subjected to this analysis, but no such analysis was conducted for cross correlation between date and time of sampling.

Distance is the river miles above the mouth of the river. Station S-12.5 was moved from river mile 12.7 to river mile 12.5 after about one year of data had been collected. These two records have been combined to form one continuous record. Total meq. denotes total milliequivalents of dissolved salts and was computed as the average of total anions and total cations. Any set of data in which one of the parameters was not reported, or in which total anions differed by more than 10 percent from total cations was discarded.

The correlation coefficients displayed in Table H-2 show the degree of intercorrelation among the 25 variables for a composite of data from the three stations. This and the following tables contain a great deal of information about the statistical relationships between water quality parameters. For instance, Table H-2 reveals that most of the variables are negatively correlated with distance, which means that the parameters are increasing in the downstream direction. Temperature and pH are notable exceptions. As expected, a high degree of positive correlation is shown between TDS, conductivity, hardness, total meq., and bicarbonates. The anticipated high correlation of both water temperature and dissolved oxygen concentration with date may also be noted. Another interesting item shown by the correlation tables is the complete lack of positive correlation between BOD and other pollution indicators, such as coliform count, total bacterial plate count, conductivity, chlorides, etc. In most instances, there is even a tendency toward negative correlation with these parameters and a positive relationship with dissolved oxygen concentration. This apparent anomaly casts doubt on the adequacy of BOD as a pollution indicator at these low levels of organic loading.

An example of the need for judicious interpretation of this information, is the high correlation between dis-

1. Date																								
2. Time																								
3. Distance	.30	.35																						
4. Calcium	.10	.08	-.21																					
5. Magnesium	.34	.25	-.31	-.54																				
6. Potassium	.27	.37	-.48	.34	-.13																			
7. Sodium	.24	.39	-.45	.36	.19	.68																		
8. Chloride	.24	.06	-.13	.37	.11	.21	.48																	
9. Bicarbonate	.34	.30	-.51	.62	.30	.67	.64	.45																
10. Carbonate	.46	.44	.01	.23	-.15	-.22	-.19	.05	0															
11. Nitrate	.11	.27	-.52	.28	.21	.80	.72	.38	.56	-.21														
12. Phosphate	.22	.28	-.34	.25	.12	.58	.64	.44	.42	-.24	.65													
13. Sulfate	.01	.31	-.43	.27	.18	.36	.58	.40	.46	-.08	.43	.45												
14. pH	.36	.22	.15	-.29	-.03	-.53	-.40	0	-.42	.26	-.41	-.26	-.24											
15. Discharge	.52	.64	-.30	-.36	.06	-.21	-.17	-.10	-.35	-.06	-.10	-.09	-.12	.23										
16. D.O.	.83	.37	-.08	.03	-.08	-.43	-.39	-.03	-.15	.52	-.21	-.34	-.13	.39	.11									
17. Ammonia	.10	.16	-.14	-.32	.36	.05	.05	.09	-.02	-.20	.10	.11	.02	.18	.18	-.01								
18. Conductivity	.23	.33	-.60	.50	.31	.71	.75	.50	.85	-.11	.71	.50	.57	-.35	-.29	-.16	.05							
19. TDS	.27	.42	-.55	.44	.33	.79	.73	.40	.83	-.19	.74	.55	.53	-.42	-.14	-.25	.74	.89						
20. Temperature	.94	.14	.21	-.04	-.03	.24	.19	-.12	.01	-.35	.01	.17	-.02	-.35	-.04	-.76	.02	.01	.06					
21. Hardness	.39	.34	-.54	.58	[illegible]	.64	.60	.49	.94	-.03	.54	.42	.48	-.37	-.37	-.13	-.01	.91	.85	-.01				
22. BOD	.63	.11	-.39	-.03	.13	.09	-.10	.07	.08	.18	.07	-.05	.06	.25	.21	.36	.02	.04	.03	-.56	.08			
23. Log (T. Count)	.39	.30	-.31	.19	.20	.46	.59	.37	.43	-.19	.51	.40	.56	-.39	0	-.42	.16	.49	.45	.34	.39	-.09		
24. Log (Colif.)	.42	.32	-.24	.14	.28	.34	.57	.27	.45	-.12	.41	.36	.55	-.40	-.08	-.42	.15	.46	.44	.19	.18	-.21	.41	
25. Total MEQ	.33	.28	-.53	.64	.29	.66	.66	.50	.99	.10	.57	.44	.50	-.39	-.35	-.10	-.03	.87	.83	-.04	.95	.09	.44	.46

N = 86

Table H-2. Correlation table for 25 variables, using data composite from three stations on the Little Bear River.

charge and time of day. This is due, not to large diurnal variations in streamflow, as might be supposed (examination of recorder tapes showed almost no diurnal variations in flow), but rather to changes in the time of sampling which happened to coincide with date.

Total meq. was dropped in further analyses because, as indicated by the high correlation coefficient, most information contributed by this computed variable is already available through directly measured variables, such as hardness, conductivity and TDS. The reduced set of 24 variables was analyzed, using a composite of data from three stations and data from each of the three stations independently. The resulting correlation tables, Table H-3, are generally comparable, with the following differences. The correlation pattern between the logarithm of coliform count and other variables is entirely different for station S-27.5 than those shown for the other two stations. Also, the correlation between dissolved oxygen and the chemical parameters at station S-27.5 differs greatly from those at the two lower stations. Correlations between D.O. and date, time and temperature are consistent from station to station, however. Analysis of the composite data indicates a high correlation between TDS or conductivity and nitrates and phosphates. This correlation disappears in the individual analysis of station S-27.5 and is much lower at station S-15.2. The high correlation is maintained at S-12.5. This indicates that care must be exercised in lumping data from more than one station to determine relationships among the water quality variables.

Specific parameter models

The correlation tables were used in screening the variables which could be included in linear models to describe the important water quality parameters. Parameters for which models are particularly needed include coliform count, hardness, TDS, pH, phosphate, and nitrate. The correlation tables indicated the futility of trying to express either phosphates or nitrates in terms of variables measured during this study. Therefore, relationships were determined by regression analysis only for the total dissolved solids (TDS), hardness (H), pH, and coliform count. The results of the analysis are summarized in Table H-4. The regression coefficients differed to some extent from station to station due to variations in the water quality regimen from upper to lower reaches of the system.

All of the models shown are statistically significant, especially those of the TDS and hardness models. Although the pH and coliform count models are statistically significant, a large amount of unexplained variation still remains. The high buffering capacity of this system, as illustrated by the high bicarbonate concentration, results in very little variation in pH levels. Some of the reported variation in pH may be caused by the colorimetric method of determination of pH which was used during much of the data gathering phase of the project. In the particular pH range encountered, it was extremely difficult to discern color changes corresponding to a pH change of 0.2 to 0.4 pH units. At a later date an electronic pH meter was obtained which improved the accuracy of pH measurement.

Summary

Complete tables of correlation coefficients have been prepared using data from 3 stations on the Little Bear River. These tables display, in a compact and concise format, information depicting the interdependence among water quality variables. The application of these tables as tools in the development of specific relationships between water quality parameters has been demonstrated.

1. Date																							
2. Time																							
3. Distance	.13	.18																					
4. Calcium	.04	.10	.16																				
5. Magnesium	.19	.32	-.57	-.55																			
6. Potassium	.27	.40	.15	.42	.22																		
7. Sodium	.13	.35	-.52	.44	.16	.76																	
8. Chloride	.16	.18	-.41	.41	.09	.48	.73																
9. Bicarbonate	.38	.19	-.36	.57	.32	.72	.61	.45															
10. Carbonate	.45	.42	.03	.16	-.19	-.24	-.20	.05	-.14														
11. Nitrate	.21	.41	-.51	.36	.21	.81	.71	.49	.62	-.27													
12. Phosphate	.22	.36	-.42	.31	.12	.66	.64	.50	.49	-.26	.68												
13. Sulfate	.08	.23	-.47	.34	.08	.41	.02	.19	.47	-.04	.37	.45											
14. pH	.24	.31	.13	-.18	-.12	-.48	-.17	-.17	-.36	.29	-.38	-.29	-.14										
15. Discharge	.46	.60	-.27	-.32	.05	-.17	.13	-.09	-.35	-.07	-.10	-.06	-.05	-.19									
16. D.O.	.77	.38	.01	-.05	-.11	-.93	-.37	-.17	-.27	.54	-.38	-.35	-.03	.38	.09								
17. Ammonia	.15	.16	-.17	-.22	.34	.14	.13	.17	.07	-.18	.13	.17	.04	.06	.12	-.11							
18. Conductivity	.22	.40	-.64	.31	.29	.77	.77	.62	.85	.14	.73	.58	.30	-.35	-.27	-.23	.13						
19. TDS	.20	.40	-.60	.48	.29	.82	.79	.59	.82	-.19	.75	.62	.50	-.37	-.27	-.30	.11	.30					
20. Temperature	.94	.72	.17	.01	-.08	.24	.11	-.11	.11	-.38	.14	.16	-.02	.21	.01	.73	.08	-.01	.04				
21. Hardness	.37	.41	-.62	.59	.33	.72	.67	.87	.92	-.08	.63	.51	.47	-.23	-.32	-.22	.08	.92	.85	0			
22. BOD	.62	.20	-.30	-.12	.11	-.03	-.06	.07	-.07	.18	-.16	-.09	.08	.18	.24	.39	-.01	-.03	-.04	-.51	-.35		
23. Log (T. Count)	.35	.28	-.40	.26	.12	.49	.60	.47	.42	-.18	.48	.45	.51	-.33	-.02	-.38	.20	.45	.43	.30	.40	-.09	
24. Log (Colif.)	.34	.23	-.38	.23	.20	.47	.53	.19	.45	-.14	.46	.43	.49	-.31	.04	-.40	.21	.45	.44	.32	.43	-.17	.80

N = 147

Table H-3A. Composite data from the three stations, S-12.5, S-15.2, and S-27.5.

1. Date																							
2. Time																							
3. Distance	.44	-.40																					
4. Calcium	.10	.20	-.04																				
5. Magnesium	.32	.32	.07	-.08																			
6. Potassium	.51	.31	.04	.38	.12																		
7. Sodium	.27	.21	.15	.41	.01	.77																	
8. Chloride	.21	.19	.19	.44	-.03	.47	.54																
9. Bicarbonate	.49	.32	0	.62	.11	.60	.61	.40															
10. Carbonate	.19	.52	.07	.11	-.19	-.30	-.15	.11	-.13														
11. Nitrate	.57	.42	-.10	.27	.19	.79	.55	.17	.61	-.30													
12. Phosphate	.49	.26	.15	.32	[illegible]	.76	.36	.25	.33	.27	.65												
13. Sulfate	.15	.67	.35	.15	-.13	.47	.49	.26	.16	-.09	.28	.49											
14. pH	.32	.40	-.06	-.09	-.28	-.51	-.44	-.21	-.41	.13	-.43	-.41	-.15										
15. Discharge	.48	.65	.10	-.30	.04	-.48	-.44	-.35	-.19	-.01	-.45	-.14	-.24	-.27									
16. D.O.	.81	.46	.02	-.16	-.11	-.12	-.01	-.10	-.42	.54	-.52	-.44	-.01	.41	.17								
17. Ammonia	.20	.13	[illegible]	-.31	.36	.01	.06	.01	-.02	-.14	-.03	-.01	-.08	.13	.11	.01							
18. Conductivity	.34	.30	-.03	.51	.12	.76	.72	.50	.78	-.19	.70	.06	.40	-.49	-.70	.38	.01						
19. TDS	.35	.25	.01	.47	.10	.79	.76	.52	.71	-.18	.72	.68	.44	-.43	-.60	-.42	-.01	.88					
20. Temperature	.98	.22	.11	.15	-.11	.47	.28	-.08	.25	-.49	.41	.45	.15	-.17	.07	-.75	.09	.18	.24				
21. Hardness	.46	.36	-.03	.61	.13	.70	.09	.58	.88	-.20	.60	.33	.18	-.46	-.13	-.40	-.01	.81	.80	-.16			
22. BOD	.62	.35	.27	-.26	.06	-.42	-.28	.02	-.35	.33	-.48	-.37	-.13	.24	.27	.43	0	-.36	-.06	-.31	-.33		
23. Log (T. Count)	.41	.11	.48	.31	.07	.48	.44	.25	.59	-.17	.42	.54	.41	-.27	-.25	-.40	-.05	-.45	.47	.43	.43	-.32	
24. Log (Colif.)	.40	.21	.51	.25	.09	.42	.50	.34	.50	-.17	.59	.47	.38	-.23	0	-.45	-.13	.17	.46	.42	.38	-.13	.73

N = 63

Table H-3B. Data from station S-12.5, 63 observations.

1. Date																							
2. Time																							
3. Distance	0	0																					
4. Calcium	.13	.17	0																				
5. Magnesium	.47	.27	0	-.71																			
6. Potassium	.42	.29	0	.24	.16																		
7. Sodium	.32	.29	0	.25	.11	.54																	
8. Chloride	.43	.09	0	.10	0	-.32	0																
9. Bicarbonate	.52	.38	0	.48	.20	.65	.57	-.06															
10. Carbonate	.61	.41	0	.31	-.25	-.22	-.17	.14	-.17														
11. Nitrate	.20	.13	0	.20	.01	.68	.27	-.15	.45	-.27													
12. Phosphate	.25	.18	0	-.01	.21	.22	.10	.18	.22	-.19	.20												
13. Sulfate	.16	.20	0	.15	.09	-.14	.26	.15	.22	.20	-.27	-.17											
14. pH	.51	.20	0	-.30	-.09	-.56	-.54	.19	-.61	.27	-.43	-.07	-.04										
15. Discharge	.51	.63	0	-.43	-.06	-.35	-.43	-.29	-.60	-.11	-.15	-.08	-.26	.27									
16. D.O.	.85	.49	0	.12	-.23	-.49	-.36	.30	-.32	.58	-.22	-.21	.07	.42	.05								
17. Ammonia	.28	.11	0	-.32	.35	0	-.08	-.11	.01	-.15	-.12	.15	-.28	.17	.03	-.09							
18. Conductivity	.35	.39	0	.47	.11	.55	.60	.06	.78	-.10	.42	.08	.31	-.51	-.65	-.15	.01						
19. TDS	.42	.45	0	.31	.23	.70	.66	-.01	.80	-.21	.48	.11	.16	-.50	-.62	-.31	-.04	.76					
20. Temperature	.97	.29	0	-.09	.16	.39	.32	-.36	.30	-.55	.16	.11	.01	-.49	.07	-.80	.13	.10	.20				
21. Hardness	.51	.46	0	.54	.16	.57	.53	.16	.86	-.01	.32	.21	.30	-.56	-.74	-.21	-.02	.88	.76	.11			
22. BOD	.51	.35	0	-.13	-.04	0	-.24	.05	-.24	.23	-.02	-.07	-.06	.42	.09	.30	-.17	-.22	-.15	-.42	-.26		
23. Log (T. Count)	.43	.19	0	.06	.11	.18	.20	-.11	.21	-.21	.06	-.10	.37	-.37	-.03	-.33	-.08	.27	.12	.43	.27	-.19	
24. Log (Colif.)	.50	.30	0	.09	.24	.25	.26	-.18	.38	-.10	.06	.06	.39	-.43	-.20	-.33	.10	.37	.22	.46	.40	-.42	.72

N = 54

Table H-3C. Data from station S-15.2, 54 observations.

1. Date																							
2. Time																							
3. Distance	0	0																					
4. Calcium	.31	.36	0																				
5. Magnesium	.52	.46	0	-.70																			
6. Potassium	.34	.13	0	.31	-.33																		
7. Sodium	.40	.43	0	.02	.19	-.11																	
8. Chloride	.65	.44	0	.40	.09	-.01	.40																
9. Bicarbonate	.93	.54	0	.22	.52	0	.35	.56															
10. Carbonate	.30	.52	0	.11	-.04	-.02	-.34	.64	-.07														
11. Nitrate	.16	.47	0	-.05	0	-.05	-.18	-.28	-.03	-.29													
12. Phosphate	.16	.16	0	.30	-.48	-.13	.12	.02	-.22	-.34	.13												
13. Sulfate	.21	.23	0	-.09	-.15	-.04	.04	-.23	-.24	-.31	-.17	.17											
14. pH	.74	.52	0	.22	.24	.21	.14	.20	.62	.20	-.19	-.24	.04										
15. Discharge	.78	.59	0	-.25	-.46	-.02	-.18	-.65	-.86	-.25	.05	.37	.43	-.55									
16. D.O.	.79	.38	0	-.10	.25	-.24	.11	.27	.12	0	.15	-.14	-.13	-.17	-.32								
17. Ammonia	.20	.20	0	-.46	.23	-.11	-.02	-.44	-.19	-.26	.04	-.05	.26	-.08	.39	-.36							
18. Conductivity	.85	.50	0	.22	.48	.03	.31	.65	.88	.05	-.05	-.39	-.28	.47	-.90	.36	-.31						
19. TDS	.67	.41	0	.24	.32	-.04	.38	.61	.73	-.15	.03	-.04	-.15	.33	-.68	.35	-.30	.81					
20. Temperature	.89	.55	0	.20	-.14	.34	-.18	-.21	.07	.48	-.18	-.15	-.12	.45	-.09	-.66	.05	-.09	-.21				
21. Hardness	.92	.58	0	.28	.49	-.07	.28	.60	.97	.10	-.06	-.27	-.31	.59	-.92	.21	-.25	.91	.73	.06			
22. BOD	.78	.50	0	-.40	.13	-.32	.13	-.05	-.27	-.49	.28	.15	.27	-.62	.34	.53	.20	-.16	-.06	-.78	-.31		
23. Log (T. Count)	.63	.47	0	-.16	-.24	.09	-.26	-.62	-.47	.02	.20	.08	.35	-.10	.62	.48	.43	-.53	-.47	.23	-.52	.07	
24. Log (Colif.)	.49	.25	0	-.23	0	-.10	-.11	-.61	-.24	.07	.15	-.13	.30	.12	.44	-.43	.45	-.37	-.44	.29	-.28	-.01	.81

N = 30

Table H-3D. Data from station S-27.5, 30 observations.

Table H-4. Summary of results of regression analyses for four quality parameters.

A. Regression of total dissolved solids (TDS) against specific electrical conductance (EC). $TDS = b_o + b_1 EC + e$

Station	N	Mean	b_0	b_1	R^2	R	R^{**}
Composite	147	283	2.07	.627	.807	.898	.212
S-12.5	63	326	-17.65	.667	.769	.877	.322
S-15.2	54	275	14.05	.602	.571	.756	.347
S-27.5	30	207	64.11	.430	.650	.806	.463

B. Regression of hardness (H) against specific electrical conductance (EC). $H = b_o + b_1 EC + e$

Station	N	Mean	b_0	b_1	R^2	R	R^{**}
Composite	147	243	48.99	.434	.848	.941	.212
S-12.5	63	268	47.79	.427	.777	.882	.322
S-15.2	54	245	45.17	.462	.769	.877	.347
S-27.5	30	189	23.30	.498	.833	.913	.463

C. Regression of pH against dissolved oxygen concentration (DO) and specific electrical conductance (EC). $pH = b_o + b_1 DO + b_2 EC + e$

Station	N	Mean	b_0	b_1	b_2	R^2	R	R^{**}
Composite	290	8.05	7.77	.0564	-.00058	.215	.464	.179
S-12.5	108	7.98	7.66	.0650	-.00051	.263	.513	.291
S-15.2	107	8.06	7.96	.0596	-.00119	.289	.538	.292
S-27.5	75	8.15	7.55	-.0086	.00199	.283	.532	.347

D. Regression of the loragithm of coliform count (Log(colif)) against sulfate (SO4), dissolved oxygen concentration (DO) and specific electrical conductance (EC). $Log(colif) = b_o + b_1 SO4 + b_2 DO + b_3 EC + e$

Station	N	Mean	b_0	b_1	b_2	b_3	R^2	R	R^{**}
Composite	236	3.99	3.13	.1440	-.1786	.00247	.387	.622	.221
S-12.5	102	4.62	4.51	.0871	-.1610	.00109	.282	.531	.330
S-15.2	88	3.69	2.03	.1937	-.1374	.00270	.299	.547	.354
S-27.5	46	3.17	8.37	.0869	-.5540	-.00196	.266	.516	.489

[a] R^2 is the coefficient of determination, R is the correlation coefficient and R^{**} is the critical value of R at the one percent level. If R R^{**}, the model is statistically significant at the one percent level.